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An assessment of the Marine Corps integrated logistics capability initiative - repair cycle time reduction

Scott, Thomas A.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ASSESSMENT OF THE MARINE CORPS INTEGRATED LOGISTICS CAPABILITY INITIATIVE – REPAIR CYCLE TIME REDUCTION

by

Troy D. Landry
Thomas A. Scott

June 2002

Thesis Advisor:	Keebom Kang
Associate Advisor:	Ira Lewis

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In this thesis, we examine the Marine Corps Integrated Logistics Capability (ILC) initiatives to reduce Repair Cycle Time (RCT) for ground equipment from 53 days to 34 days by fiscal year 2006 (a 35 percent reduction). Based on Little's Law, the Marine Corps could save a substantial amount of money on inventory and improve operational availability of its weapon systems by reducing RCT. We used ARENA simulation software to construct a baseline model of the current maintenance process. We then made modifications to the baseline model to test the Marine Corps' prediction that the proposed ILC initiatives of maintenance consolidation will result in a 35 percent RCT reduction. Our final simulation model focused on future changes that will reduce RCT by 50 percent. We find that based upon the consolidation of maintenance echelons that the Marine Corps is only able to reduce RCT by 32.5 percent. We find that a 10 percent reduction in retail Order Ship Time (OST) and other maintenance processes will allow the Marine Corps to meet the RCT goal of 35 percent reduction. We find that the reduction of additional maintenance processes coupled with variance reduction of retail OST can reduce RCT by 50 percent.

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Troy D. Landry
Major, United States Marine Corps
B.A., Lamar University, 1992
and
Thomas A. Scott
Lieutenant, United States Navy
B.S., Otterbein College, 1993

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requirements for the degree of

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NAVAL POSTGRADUATE SCHOOL
June 2002

Authors:

Troy D. Landry

Thomas A. Scott

Approved by:

Keebom Kang, Principal Advisor

Ira A. Lewis, Associate Advisor

Douglas A. Brook, Dean
Graduate School of Business and Public Policy

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LIST OF ACRONYMS

AIS	Automated Information System
Ao	Operational Availability
CNA	Center for Naval Analyses
CSSE	Combat Service Support Element
DOD	Department of Defense
EOM	Echelons of Maintenance
ERO	Equipment Repair Order
EROSL	Equipment Repair Order Shopping List
FMC	Fully Mission Capable
FSSG	Force Service Support Group
GCSS	Global Combat Support System
GUI	Graphical User Interface
ILC	Integrated Logistics Capability
IMA	Intermediate Maintenance Activity
IPT	Integrated Product Team
IT	Information Technology
MAGTF	Marine Air-Ground Task Force
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MIMMS	Marine Corps Integrated Maintenance Management System
MMO	Maintenance Management Officer
MTBM	Mean Time Between Maintenance
MTVR	Medium Tactical Vehicle Replacement
NMC	Non-Mission Capable
NSN	National Stock Number
OST	Order Ship Time
QC	Quality Control
RCT	Repair Cycle Time
SECREPS	Secondary Reparables
SMU	SASSY Management Unit
SOS	Source of Supply
SRAC	System Realignment and Categorization
TM	Technical Manual
USMC	United States Marine Corps
WIP	Work-in-Progress

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I. INTRODUCTION

> Change is the law of life. Any attempt to contain it guarantees an explosion down the road; the more rigid the adherence to the status quo, the more violent the ultimate outcome will be.
>
> Henry Kissinger

A. BACKGROUND

The Marine Corps leads other services in the planning and execution of expeditionary logistics, but it must continue to adapt to the changing demands of 21st century warfare. The end of the Cold War has led to a reduction of U.S. military forward presence abroad, and all services are now being required to adopt logistics in support of expeditionary missions. In *Joint Vision (JV) 2010* and *Joint Vision (JV) 2020*, the Department of Defense (DOD) addresses the need for change and provides a framework in which to accomplish that change. "The conceptual documents contained within the *Marine Corps Warfighting Concepts for the 21st Century*, particularly *Operational Maneuver From the Sea (OMFTS)* and *The MAGTF (Marine Air-Ground Task Force) in Sustained Operations Ashore*, provide the operational framework for execution of that vision on the battlefield and define the context within which logistics/combat service support will be provided." (Love & Collenborne, 2001)

The Marine Corps has taken JV 2010 and JV 2020 and developed an initiative called Integrated Logistics Capability (ILC) that looks for tactical solutions to support the DOD's strategic vision.

1. Overview of ILC Initiative

In January 1997, the Commandant of the Marine Corps issued a policy letter that provided initial guidance for the restructuring of expeditionary logistics support by taking advantage of information and speed in order to replace enormous stocks of supplies. Further research was conducted on this topic by a team of military personnel, industry leaders and academia, and in March 1998, the team published the Integrated Logistics

Capability Case Study. This study identified important areas of improvement on which the Marine Corps should focus. It also provided a guide for reengineering logistics processes in the Marine Corps. Subsequently, ILC Integrated Product Teams (IPT) were created to investigate different logistics areas in September 2000. (USMCI&L, 2001)

"The ILC initiative is designed to facilitate the development, integration, and fielding associated with emerging logistics capabilities by: (1) creating an environment that enables or supports continuous improvement of business practices, (2) ensuring maximum available operational capabilities and processes, and (3) minimizing the forward-deployed logistics footprint." (U.S. Department of Defense, 2001) One key to achieving these capabilities is through the reduction of the Marine Corps' Repair Cycle Time (RCT) for ground equipment.

2. Cycle Time Reduction

On 14 September 1994, Secretary of Defense Dr. William Perry sent a memorandum to all components of the military expressing the need to reduce cycle time (Perry, 1994):

> The private sector has found that attacking business-process cycle times is a powerful weapon in its reengineering arsenal which generates more efficient processes, greater product quality and improved organizations for less cost. I am convinced that by focusing on cycle time reduction, we can springboard from our existing total quality and Defense Performance Review initiatives to vastly more substantial gains in achieving the Vice President's [Al Gore] goals of reducing infrastructure, streamlining and improving customer service…Time is money. By consuming our people's time with lengthy processes, we forfeit their ability to contribute to warfighting. We pay enormous and unnecessary infrastructure costs that limit our ability to fund warfighting requirements as well as research and development.

What is cycle time? Why is the reduction of cycle time so important to the Marine Corps? Our thesis will answer these questions and demonstrate the effect of cycle time reduction through the use of the ARENA 5.0 simulation software. (Kelton et al., 2002)

First, what is cycle time? For the purpose of this thesis, cycle time is defined as the time it takes to repair a weapon system and return it in an operational condition to the warfighter. To illustrate, first consider that a Marine is driving a truck and his transmission fails. The cycle time begins once the truck fails. The Marine is able to drive the truck to the maintenance shop and the vehicle is inducted into the maintenance process. The cycle continues until the maintenance process has returned the vehicle to the Marine in an operational condition. For the purpose of our thesis cycle time will be measured in days.

The best way to understand the effects of cycle time reduction is to review its relationship with equipment operational availability.

Ao = Uptime / (Uptime + Downtime)

or

Ao = Number of Mission Capable Assets/Total Number of Assets

Uptime is the Mean Time Between Maintenance (MTBM), which includes both corrective and preventive actions. Downtime is maintenance-related down time, "… which includes repair time and administrative and logistics delay times." (Kang, 1998) There are two ways to increase operational availability. First, the reliability of the weapon system can be increased, thereby improving MTBM. This option is normally fiscally constrained during the weapon system's acquisition process. Based on the weapon system's budget, there is only so much reliability that the Marine Corps can purchase before it becomes unaffordable. Second, by reengineering the maintenance process, the Marine Corps can reduce the downtime related to repair time and administrative and logistics delays. This will save on infrastructure cost and weapon system inventory cost in the long run.

According to the Center for Naval Analysis (CNA) *USMC Integrated Logistics Capability Proof of Concept Baseline Assessment*, there exists some variation in operational availability of weapon systems in the Marine Corps. CNA measured material readiness rates for 2nd Force Service Support Group (FSSG), 2nd Marine Expeditionary Force (IIMEF), Camp Lejeune, North Carolina, from April 2000 to May 2001 and found that communication and ordnance systems' readiness rates range from 87.9 percent to 98 percent. Engineering systems' readiness fluctuated from 84.1 percent to 90.1 percent. Motor vehicle systems' readiness had the widest range from 75.5 percent to 90.4 percent. (Heybey, 2001) Therefore, operational availability of systems may be a significant problem. Additionally, the amount of inventory that must be maintained to ensure the Marine Corps can maintain a high state of readiness is an unnecessary waste of taxpayer dollars.

For example, assume that the Marine Corps will accept an operational availability of 90 percent for all trucks. Let us also assume that the Marine Corps' current inventory consists of 100 trucks. This means that the Marine Corps' maintenance process must keep 90 trucks Fully Mission Capable (FMC) and that at any time there are no more than 10 trucks in the repair process in a Non-Mission Capable (NMC) condition.

After further mission analysis the Marine Corps determines 95 FMC trucks are required. There are two ways that the Marine Corps can meet this goal. First, they can maintain the current maintenance process that has at any time 10 NMC trucks in the repair process. This will require the Marine Corps to purchase 6 additional trucks. (95 = 105.6 FMC*0.9). At a unit cost of $135,000, this would cost the Marine Corps $810,000.

The second and most reasonable option is for the Marine Corps to reengineer the maintenance process in order to reduce RCT, so that more trucks are FMC and less are NMC. Based on our scenario, this would require reducing RCT so that at any time there are 95 trucks FMC and only 5 trucks NMC. (.95 = 95/100).

Cycle time reduction will reduce the inventory of equipment that is needed in order to achieve readiness. This translates into the reduction of piece parts that need to be kept on hand to maintain these systems. This overall reduction in equipment inventory will also reduce inventory-carrying costs. It is the Marine Corps' goal to reduce inventory from $1.2 billion to $600 million, and inventory carrying costs from $240 million to $120 million by fiscal year 2006. Another goal is the reduction of contingency sustainment footprint from 231,792 tons to 127,485 tons by fiscal year 2006. (Heybey, 2001)

All of these goals can be accomplished by the reduction of RCT. Based on Little's Law (Little, 1961), inventory reduction is directly proportional to a reduction in cycle time:

AVERAGE INVENTORY = THROUGHPUT RATE x REPAIR CYCLE TIME

With throughput being a constant, this formula shows how just reducing inventory, without consideration for cycle time reduction, would harm the maintenance system. Therefore, based on our example, the Marine Corps has an average inventory of 10 trucks at any one time in the maintenance process. The Marine Corps' current average RCT is 53 days. (Heybey, 2001) Based on Little's Law, the throughput rate is .18868 trucks per day (10/53 = .18868). In order for the Marine Corps to reduce the average inventory of trucks in the maintenance process from 10 to 5 it will have to reduce RCT by 50 percent (5 trucks = .18868 trucks per day x 26.5 days). In order to accomplish this the Marine Corps must eliminate non-value added activities in the maintenance process, reduce the variance of value added activities and reduce the average cycle time of each activity.

B. AREA OF RESEARCH

Our thesis research will examine the Marine Corps Integrated Logistics Capability (ILC) initiative, specifically the idea of RCT reduction. Our first goal is to evaluate the Marine Corps' existing maintenance process against proposed initiatives that could possibly reduce equipment RCT from 53 days to 34 days by FY 2006. Our second goal is to identify additional actions that could be taken to reduce RCT by 50 percent (from 53 days to 26.5 days). We will base our research on the following ILC hypotheses:

Hypothesis 1: Support will become more responsive to the customer, as there will be fewer non-value added steps and thus a direct link to the intermediate level of maintenance. (Heybey, 2001)

Hypothesis 2: Economies of scale will be gained as the overall administrative burden associated with monitoring parts (Preexpended bins (PEB)), layettes, maintenance records and the like will be lessened. (Heybey, 2001)

Hypothesis 3: Labor productivity will increase, as maintenance sites will have a more streamlined approach due to the elimination of the Echelons Of Maintenance (EOM's) and a focus/redefinition of intermediate maintenance. (Heybey, 2001)

C. RESEARCH QUESTIONS

In order to address these hypotheses, we will attempt to answer the following questions:

1. Will the elimination of identified non-value added activities in the maintenance process be sufficient to meet the Marine Corps' RCT goal of 34 days by FY2006 (a 35 percent reduction)?

2. Given the elimination of identified non-value added activities in the maintenance process, how much will RCT decrease by reducing the Order Ship Time (OST) for repair parts?

3. Given the elimination of non-value added activities in the maintenance process, how much will RCT decrease by reducing administrative burdens on maintenance personnel?

4. What is required to reduce RCT by 50 percent?

D. DISCUSSION

> Although our equipment readiness remains relatively high, we still find Marines waiting weeks for a vehicle to be fixed. Within our supply chain and maintenance repair processes we find **too much variability and non-value added activities taking place.** Examples include redundant inspections, excessive time waiting for parts, and a host of administrative chores that do not contribute to improving equipment availability or saving Marines time.
>
> Lieutenant General McKissock

The Marine Corps is looking for ways to improve equipment RCT from months to days like the commercial sector. ILC is the Marine Corps' initiative to take the current ground equipment maintenance process and transform it into a process that will support the Marine warfighter for the challenges of 21st century warfare.

E. METHODOLOGY

Our thesis will utilize simulation models to meet our objectives and demonstrate how a reduction in RCT affects inventory and increases operational availability for Marine Corps equipment. We will first conduct a thorough review of the current Marine Corps' ground equipment maintenance process. Then we will research the ILC initiatives that deal with reducing RCT. This information will provide the basis for our simulation model. For model examples we will focus on motor vehicles, specifically tactical combat trucks, since they represent the system with the widest variance of operational availability.

The simulation model will be based on data gathered from the CNA ILC study, *USMC Integrated Logistics Capability Proof of Concept Baseline Assessment.* Supply Order Ship Time (OST) data will be gathered from the Marine Corps Precision Logistics Office. Some of the maintenance process data of the current maintenance process will be based on the RAND National Defense Research Institute study, *Measurement of USMC Logistics Processes: Creating a Baseline to Support Precision Logistics Implementation.* Other maintenance process data will be based on personal observation.

Our study will be limited to examining the maintenance process from 1st to 3rd Echelons. Transportation Support Battalion, 2nd Force Service Support Group (FSSG), 2nd Marine Expeditionary Force (IIMEF), Camp Lejeune, North Carolina, will represent 1st and 2nd Echelon since they rely heavily on trucks to support their mission. The Intermediate Maintenance Activity (IMA), 2nd FSSG, IIMEF, Camp Lejeune, North Carolina, will represent 3rd Echelon maintenance activity.

Once the data is gathered we will construct a baseline simulation model of the current ground equipment process. We will use the simulation software package ARENA

5.0 to construct our model. (Kelton et al., 2002) We will then create different maintenance process scenarios by altering the baseline model.

Our first scenario will examine the ILC concept of consolidated maintenance. The second scenario will build on the first by applying the different ILC hypotheses of what should take place once the maintenance process is consolidated. Our final scenario will enhance the previous scenarios by examining what is required in order to reduce RCT by 50 percent.

Once all the scenarios have been replicated and measured, we will analyze and determine the effect these changes will have on inventory levels and operational availability.

F. STRUCTURE OF THE THESIS

Our thesis will be structured into six chapters. Chapter I has provided a broad overview of the thesis subject, stated the objective of our thesis, identified research questions, described the scope of our research effort and presented our research methodology. Chapter II discusses one of the author's personal experience with the "administrative chores" of the maintenance process, ILC changes to the current ground equipment maintenance process, ILC changes to the current ground equipment supply process and ILC proposals to reengineer both maintenance and supply information technology. In Chapter III we provide an overview of modeling and simulation by answering the question: What is modeling and simulation? Then we describe the steps in developing a simulation model. In Chapter IV we present the ARENA simulation model of the current ground maintenance process and the simulation models that support our three scenarios. In Chapter V we present a comparative analysis of our three simulation scenarios against the baseline simulation model of the current Marine Corps ground maintenance process. Chapter VI presents a summary of our thesis research, conclusions and recommendations for future study.

II. INTEGRATED LOGISTICS CAPABILITY

In this chapter we will provide a broad overview of what the Marine Corps Integrated Logistics Capability (ILC) initiative consists. First, we will provide a review of the "administrative chores" of the maintenance process based on one of the author's experience as a Battalion Maintenance Management Officer. Then we will examine ILC's three distinct parts. We will provide an explanation of the ground equipment maintenance process by looking at the current process and then reviewing ILC proposed changes. Then we will provide an overview of the ground supply process by comparing the current process to the ILC proposed quadrant model. We will conclude this chapter by considering how reengineering information technology plays a major role in determining the success of the maintenance and supply initiatives.

A. REVIEW OF "ADMINISTRATIVE CHORES" (BASED ON MAJOR LANDRY'S EXPERIENCE)

Upon my completion of the Marine Corps Logistics Officer Course in 1993, I was assigned as the Maintenance Management Officer (MMO) for an artillery battalion, Fifth Battalion, Eleventh Marines, located at Camp Pendleton, California. An artillery battalion's primary weapon systems include 18 M198 (155mm) towed howitzers, 58 five-ton trucks, and approximately 75 different communication assets.

My job as the battalion MMO was to manage the battalion maintenance process and institute processes that would improve the battalion's equipment readiness. I was also charged with the responsibility of ensuring battalion compliance with Marine Corps maintenance policies and procedures. Regimental and Division headquarters monitored our equipment readiness weekly and inspected our compliance with policy annually. The greatest emphasis was on the weekly readiness information. If we fell below 90 percent readiness, I would provide explanations and corrective courses of action to the battalion commander, who in turn would provide the same information to the regimental commander.

The system used to monitor the Marine Corps' ground equipment maintenance process is *The Marine Corps Integrated Maintenance Management System (MIMMS)*. The management of this system is based on laborious paperwork. It requires the completion, coordination, and management of numerous hard copy documents. For example, if a five-ton truck needs a repair, the mechanic fills out an Equipment Repair Order (ERO) form, which provides carbon backing to produce three copies. The ERO tracks the chronological history of all maintenance performed and records such information as vehicle mileage, description of work and the time needed to complete each task. The master copy is maintained in the equipment record jacket, the mechanic uses the second copy to annotate any changes and the data entry clerk uses the third copy.

The mechanic consults a technical manual (TM) that provides trouble-shooting tips and schematics about the parts involved in the repair. Once the problem is identified, he reviews the TM for the National Stock Numbers (NSNs) of the repair parts. The mechanic then fills out an Equipment Repair Order Shopping List (EROSL) in triplicate. This is an 80-column form that records the 13 digit NSN, the ordering priority and the associated ERO. The master copy is maintained in the equipment record jacket. The supply clerk uses the second copy to input the repair order in the supply system. The warehouse uses the third copy to track the parts once they arrive. Unfortunately, this complex and labor-intensive system wastes too many man-hours, which reduces the battalion's readiness.

The Repair Cycle Time (RCT) measures the number of days it takes to identify a repair requirement, fill out paperwork to order the part, receive the part and install, close out the paperwork and return the equipment to the warfighter. Some of the RCT problems stem from the documents that the mechanic must complete and manage for MIMMS to work properly. The problems can be divided into three main components: systemic, organizational, and human error.

At the Logistics Officer Course, I spent a month just trying to understand MIMMS and how to analyze the reports that are produced. In contrast, the mechanic receives only one week of MIMMS training at school, which gives him only a basic familiarity with the system. The majority of learning is conducted on the job. Human misunderstanding is the primary cause of errors in reporting equipment status because the system relies heavily on hard copy documentation. The mechanic must learn how to properly maintain and fix complicated types of motor transportation equipment and also learn the codes and symbols that are used to operate MIMMS. For example, each repair must be coded in order to properly classify the type of repair that is being accomplished. An "M" is recorded in block 15 on the ERO and column 23 of the EROSL in order to describe the repair as mission critical. In addition, the mechanic must understand the Department of Defense Force Activity Designation in order to determine the priority of maintenance and supply orders. It takes mechanics about six to nine months to understand how to properly fill out the documents for MIMMS.

Organizationally, Fifth Battalion, Eleventh Marines was just like the other battalions in the regiment in its effort to maintain a high state of equipment readiness. My battalion rated approximately 20 mechanics to be 100 percent staffed; however, throughout my three-year tour we averaged 12 to 15 mechanics. These Marines routinely put in 10-12 hour days in order to ensure that the equipment was above 90 percent readiness. This often forced mechanics to fix the vehicle immediately and worry about the paperwork later. I estimate that about 20-30 percent of the paperwork for equipment repairs was either partially or never filled out or entered into MIMMS. An additional 10 percent of the paperwork was filled out and subsequently misplaced. This required the mechanic to spend additional time recreating the paper trail. Therefore, the weekly MIMMS report used to reflect battalion readiness did not have current information; it was always at least three to five days behind what was actually taking place in the shop. Due to a complicated and labor-intensive maintenance system, as well as the pressure of this weekly report, MIMMS became useless as a management tool.

In addition to the mechanic's daily duties of repairing vehicles, he is also responsible for collateral jobs. Most of these jobs are interrelated to daily operations of the shop. A good example is when a mechanic is assigned as the TM publications clerk. It is his responsibility to maintain the hard copy TMs, including any equipment modifications. Additionally, he must review any quarterly updates, which are distributed via compact discs. These updates would include changes to NSNs, part numbers, and repair procedures. Once he identifies the updates, he fills out an EROSL to order the publications. He must take the EROSL to the supply clerk to be entered into the battalion's supply order system. It takes approximately 30 days to receive the update, at which time the mechanic makes the appropriate changes to the hard copy of the TM, which may include page insertions or a complete replacement of the TM. The publications clerk must make sure outdated information is replaced in a timely manner. If he does not, mistakes result such as annotation of wrong NSNs and part numbers, or even the failure to apply critical modifications to equipment.

An unacceptable level of human error is present in these additional duties due to this cumbersome system. MIMMS forces Marines to accomplish tasks in a constrained time frame, which results in mistakes, frustration and low morale. Marines question why the Marine Corps is not able to quickly adopt commercial maintenance processes and current Information Technology (IT) applications which would allow them to complete their mission in days rather than months. In 1993, these Marines understood that the Marine Corps must reengineer the maintenance process and implement IT solutions, which will allow the Marines to become more efficient. Fortunately, possible solutions that could eliminate these frustrations are being addressed through the ILC initiatives.

B. REFORMING THE GROUND EQUIPMENT MAINTENANCE PROCESS

The ILC team spent time with industry leaders and academia at Pennsylvania State University learning how commercial industry does business. The ILC team initially thought that it would learn about best-business practices and then research possible IT solutions to address the Marine Corps' logistics problems. However, they discovered that in order to implement industry best-business practices, they must first examine current Marine Corps logistics business processes. (USMCI&L, 2001)

In order to improve equipment RCT from months to days like the commercial sector, ILC examined the main factors causing the delays. They reviewed the current maintenance process and identified non-value added activities. The major focus is to shift most of the logistics burden from the warfighter to the Combat Service Support Element (CSSE) of the Marine Air Ground Task Force (MAGTF). (USMCI&L, 2001)

1. Current Process

The current Marine Corps Maintenance Process is broken into five Echelons of Maintenance (EOM). The equipment operators perform 1st EOM, which covers primarily Preventive Maintenance (PM) procedures. 2nd EOM is performed by the using unit, for example an artillery battalion, and includes maintenance that requires trained technicians to perform detailed disassembly of the equipment. 3rd EOM is performed by the intermediate maintenance activity. 4th EOM takes care of Secondary Reparables (SECREPS), which are reparable components to major weapon systems (e.g. engines, transmissions, alternators, etc.). 5th EOM is where major rebuilding of equipment is performed.

The maintenance activities performed by 3rd EOM personnel are virtually the same as those performed by the maintenance personnel at the 2nd EOM. The mechanics and technicians at both 2nd and 3rd EOM have equivalent skills and training and often have access to the same type of tools. Equipment that is identified for repairs, which is required by Marine Corps policy to be corrected at the 3rd EOM, will have many of the same maintenance tasks (e.g. inspections, quality control and parts ordering) performed at both the 2nd and 3rd EOMs. (USMCI&L, 2001).

The redundancy of non-value added activities (e.g. inspections, repairs, ordering of parts, quality control and transportation) has increased RCT. According to Lieutenant General McKissock, Deputy Commandant for Installation and Logistics, "His own records indicate that, every time a piece of equipment goes into the repair shop, only 10 percent of the time is spent 'turning wrenches.' The remaining 90 percent of the time, 'we are ordering parts, we are inspecting, we are moving between echelons'". (Erwin, 2001)

2. Recommended Maintenance Process

To improve the maintenance process, ILC recommended changing the process from five EOMs to three EOMs. This change would involve:

(1) Relocation of second and third echelons of maintenance to the intermediate level.

(2) Relocation of fourth echelon maintenance and secondary reparable management to depot level [5th EOM]. (Love & Collenborne, 2001)

Combining 2nd & 3rd EOM at the intermediate level eliminates the redundant functions within the maintenance process. "The process supports the concept of the CSSE Commander becoming the single process owner for maintenance in the MAGTF. Because the resources necessary to perform the process are under his control, there will now be more flexibility to make adjustments to support efficiencies and effectiveness based on mission needs and priorities." (USMCI&L, 2001) This change is predicted to save a substantial amount of money by reducing the number of maintenance facilities, tool rooms, and parts inventory. The bigger effect is to increase the "tooth to tail ratio" by eliminating redundant logistical jobs. According to Colonel Love, Head of the ILC Center, "Within the existing 168 organizational-level shops in the Marine Corps, there are 3,205 maintenance workers and 1,269 supply personnel. 'There is redundancy in this area, we think we can use these people better.'" (Erwin, 2001)

The movement of 4th EOM of SECREPS to 5th EOM will centralize the Marine Corps' maintenance effort at one level, for many of the same reasons they recommend moving 2nd to 3rd. Additionally, this movement will provide for a just-in-time inventory management by leveraging IT. According to the ILC team, the centralized capability will have the following benefits: "responsive and reliable distribution system, web based real-time or near real-time distributed information management, precision stock positioning and posture and total SECREP asset visibility." (USMCI&L, 2001)

C. REFORMING THE GROUND EQUIPMENT SUPPLY PROCESS

> Today, the delivery of goods and services is commonly viewed as occurring within a supply chain consisting of various levels or nodes. It begins at the ultimate customer-the consumer-and extends backward through various retail/intermediate, wholesale/depot, and vendor levels.
>
> Love & Collenborne

In order to adequately support the concept of OMFTS, the Marine Corps must streamline its supply process and move from the mindset of maintaining massive inventories to exploiting velocity. The ILC team reviewed the current supply process and discovered enormous amounts of inventory at each level of the supply chain. Additionally, ILC participants realized that there was no clear understanding of core competencies along the supply chain. (USMCI&L, 2001)

The ILC team recommended consolidating selective functions from the using unit to CSSE. CSSE will become the "critical link in the supply chain." (Love & Collenborne, 2001) The rationale for making the CSSE commander responsible for the upstream and downstream flow of supplies is that it allows the warfighter to focus his attention on his primary combat mission of shooting, moving and communicating in support of OMFTS. (USMCI&L, 2001)

1. Current Process

The Marine Corps' current supply system is focused on supporting another war like the Gulf War, which relied upon massive amounts of equipment and supplies. Most battalions are currently maintaining "just-in-case" inventories of supplies because the supply system is not responsive.

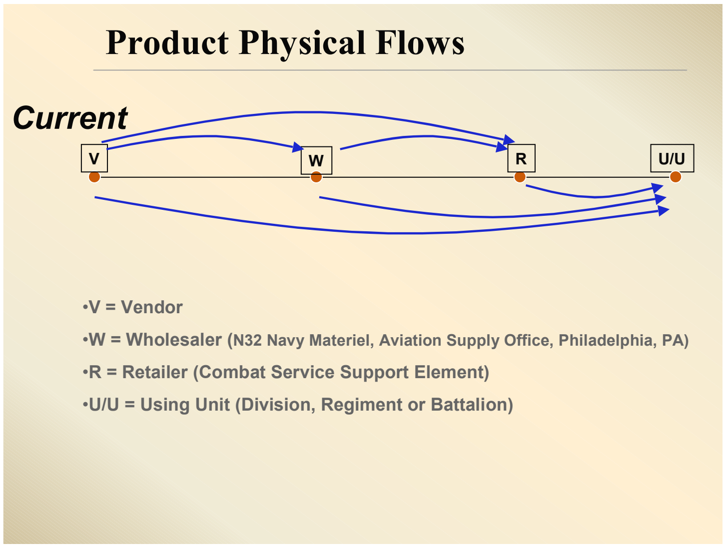

Figure 1. Current Product Physical Flows (After: Col J.A. O'Donovan)

The Marine Corps currently relies on inventory that is stored at each link in the supply chain (see Fig 1 above). In order to accomplish its combat mission each link maintains a massive supply of inventory rather than relying on "Precision Logistics." According to one estimate, this inventory amounts to approximately $1.2B. (USMCI&L, 2001) From the warfighter's viewpoint mass is better than not having what you need in time of war.

2. Recommended Supply Process

ILC has recommended the following changes to the Marine Corps supply process:

(1) Consolidation of selected using unit supply responsibilities at the retail level.

(2) Institutionalizing the Quadrant Model for material management. (USMCI&L, 2001)

Consolidation of the selected using unit supply responsibilities at the retail level is predicted to produce the same benefits as consolidated maintenance. The Quadrant Model will allow the Marine Corps to categorize supply inventory based on its uniqueness and value. It is predicted that use of the Quadrant Model will improve supply chain management and provide better support to the warfighter.

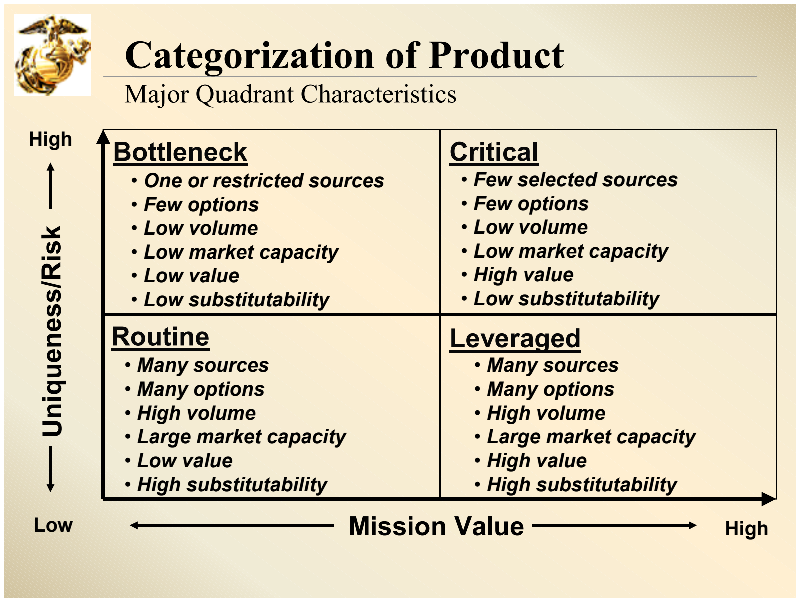

Figure 2. Quadrant Model (From: Col J.A. O'Donovan)

The Quadrant Model is broken down into four product categorizations: routine, bottleneck, leveraged and critical. Figure 2 above lists the characteristics that distinguish each categorization.

Routine products are identified as low uniqueness and low mission value for the Marine Corps. These products are easy to acquire from multiple Sources Of Supply (SOS), which means that the Marine Corps can function without maintaining an inventory of these items. Vendors can usually provide routine items as they are required by the warfighter. Figure 3 below shows how routine products flow from multiple SOS to the using unit.

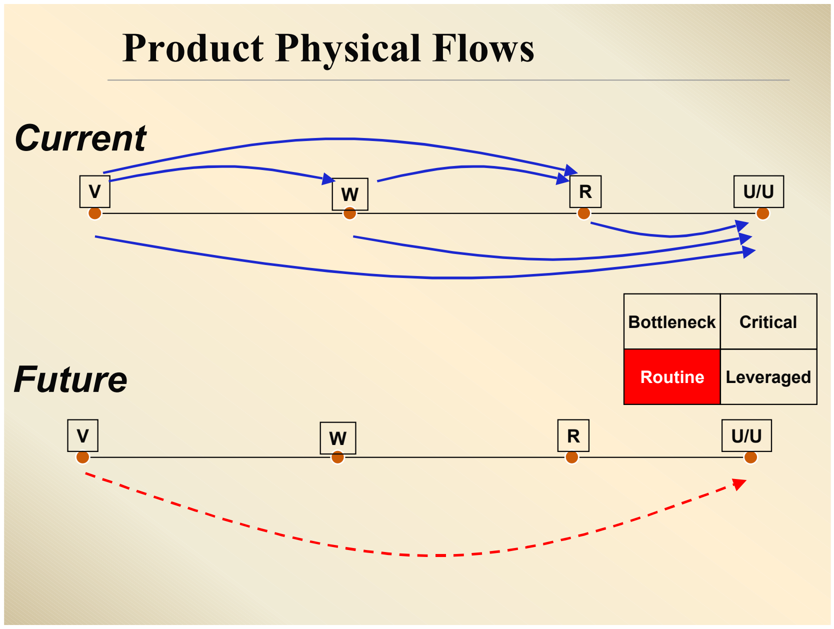

Figure 3. Routine Product Physical Flows (From: Col J.A. O'Donovan)

Bottleneck products are those that are highly unique and represent low mission value for the Marine Corps. However, there are few SOS that can provide bottleneck items. The recommendation is that the wholesaler select only those vendors who have the industry reputation of being able to deliver bottleneck products when needed. The management strategy is to collaborate with vendors so that in the long run OST is improved for these items. The wholesaler will maintain an inventory of bottleneck products, even supply items that have low turnover. This will provide insurance stocks so that the wholesaler can meet the warfighter's requirement. Figure 4 below shows how the wholesaler will receive and store bottleneck products from the vendor. When a bottleneck product is needed by the using unit the wholesaler will push the item forward.

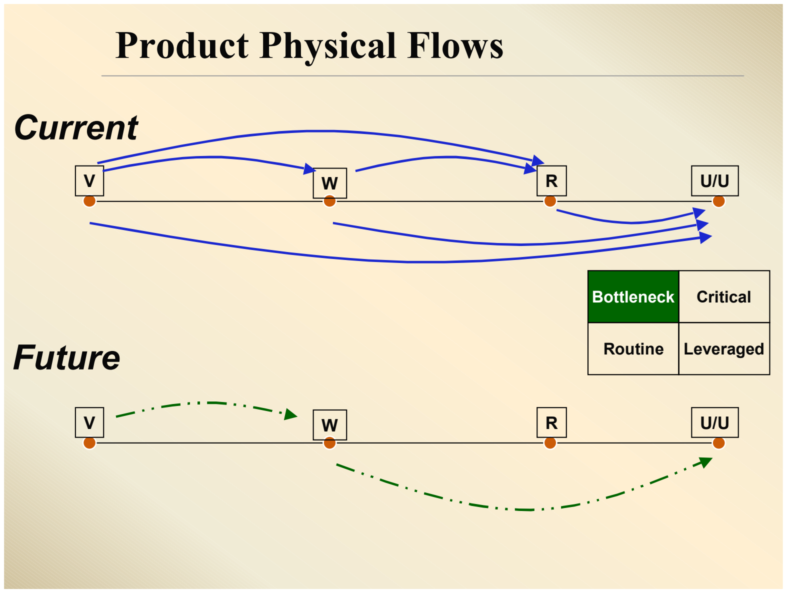

Figure 4. Bottleneck Product Physical Flows (From: Col J.A. O'Donovan)

Leveraged products are identified as valuable to the mission of the Marine Corps but not unique. There are a number of SOS, therefore minimal inventories are needed at the retail level. Even though these supplies have a high mission value, the retailer can demand that suppliers compete in order to ensure a good price. Figure 5 below shows how leveraged products will be distributed in the future.

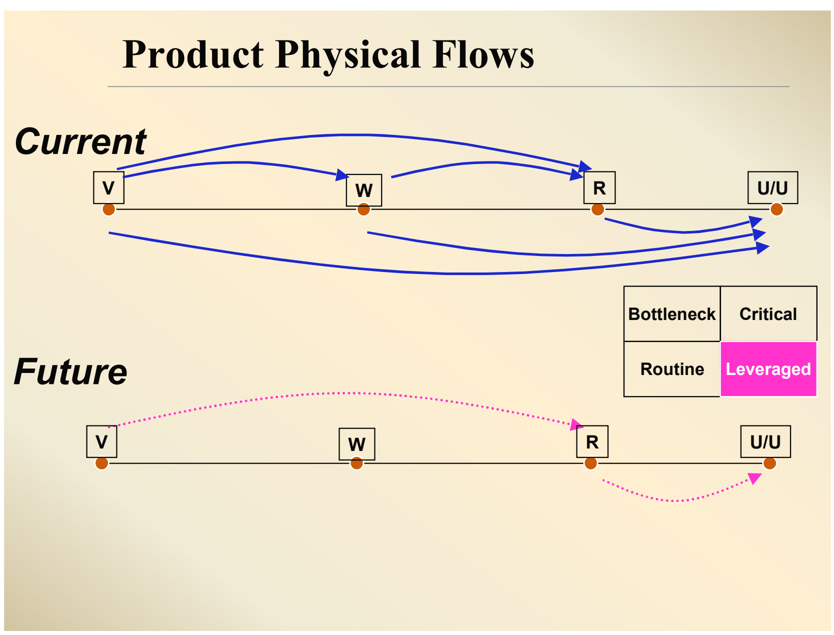

Figure 5. Leveraged Product Physical Flows (From: Col J.A. O'Donovan)

Critical products are both highly unique and high in mission value. One important characteristic is that there are few, or in some cases only one SOS. The value of the product replaces price as the driving factor when considering vendors. Therefore, the Marine Corps should evaluate vendors based on quality and develop long-term relationships in order to ensure that quality is maintained. Inventories at all nodes of the supply chain are normal, but by developing a long-term relationship the Marine Corps is able to share information with vendors regarding future demand in order to optimize inventory levels. Figure 6 below shows how critical products will be maintained at each node of the supply chain.

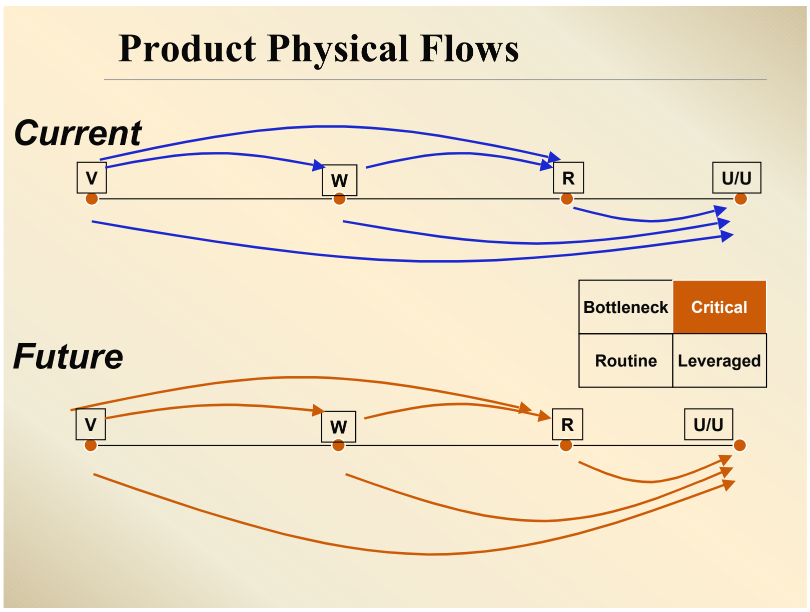

Figure 6. Critical Product Physical Flows (From: Col J.A. O'Donovan)

The adoption of this Quadrant Model will require the Marine Corps to manage multiple supply chains, based on the characteristics of the products in each quadrant. Doing away with the old process of a single supply chain, with all products being treated as critical, is expected to save money and time from managing multiple inventories at multiple levels. According to Colonel Love, "Today, the way we manage inventory, we pretty much try to move everything forward. That means we tie up people and airlift assets. In the future we will only push forward things that are critical and have high mission value." (Erwin, 2001)

Currently, according to a May 2002 ILC situation report, the consolidation of supply functions within 2nd FSSG is complete. The Quadrant Model began testing at 2nd FSSG on 2 May 2002. The next phase will include simplifying financial accounting and developing automatic supply receipts procedures, which will rely heavily on Information Technology (IT).

3. Reengineering Information Technology

Today, the Marine Corps is trying to enter the Operational Architecture phase for IT, and continues to maintain more than 200 logistics Automated Information Systems (AISs), many of which are redundant. The ILC team is now reviewing ways of reengineering IT in order to support the new maintenance and supply processes. The emphasis is on reducing the number of legacy systems and ensuring that future IT logistics systems are integrated. (USMCI&L, 2001)

The ILC team developed a method called System Realignment and Categorization (SRAC) to reduce the number of redundant Marine Corps logistics applications. SRAC will review the logistics AISs across all functional areas (e.g. transportation, supply, maintenance, etc.) SRAC is divided into three progressive phases:

Phase 1 – Concentrates on discovering "no-value" AISs and retiring them. No value AISs are those which have either no users, no funded support, or are unsupportable because they use obsolete technology.

Phase 2 – Identifies "low-value" AISs. Primarily, these are systems that support a low number of logistics functions and a low number of users. Low-value AISs will be retired and their required functionality will be migrated to other systems.

Phase 3 – Identifies "high-value" AISs that support many logistics functions and a large number of users. Migration and integration plans will be developed to consolidate these AISs to a manageable number. (USMCI&L, 2001)

Once the ILC team has completed SRAC, it will produce a list of legacy and emerging AISs that will participate in the DOD mandated Global Combat Support System (GCSS). GCSS "…was established as a DOD-wide initiative to achieve information superiority in the area of logistics…. [it] is a strategy for 'enhancing combat support effectiveness through improved system interoperability between currently disassociated and independent applications, systems and data.'" (Ferris, 2001)

D. CHAPTER CONCLUSION

The ILC initiative is the first step in preparing Marine Corps logistics to meet the nation's security needs of the 21st century. The ILC team has been able to synthesize the DOD mandates of JV 2010 and 2020 (focused logistics) into tactical methods of application.

The reengineering of the maintenance, supply and information technology processes is the first big step in this transformation. The Marine Corps' relationships with industry leaders and academia will serve it well in the steps that follow. As good as the first step has been, there are possible implications that should be addressed. For instance, there may be resistant to changing the status quo. Opposition to the ILC recommendations may come from those commanders who like having control over their own logistical support. They may believe that having the supply and maintenance personnel under their command and control is more effective than relying on other people outside their span of control. Some commanders may fear that the recommended change in supply will not be responsive to their combat requirement. Lieutenant General McKissock recognizes that this opposition is legitimate:

> The work we are doing to redefine and fundamentally change our processes is not easy-it is difficult and takes time. Further, it is difficult to overcome existing cultural resistance to change, which is compounded by the fear of the unknown. Despite these challenges, we will see dramatic improvements taking place with the next 24 to 36 months.
>
> Lieutenant General McKissock

Increasing the "tooth to tail ratio" has become a popular phrase when discussing logistic reengineering efforts. The ILC team proposes savings by eliminating two EOM and consolidating supply functions from the using unit to the retail level. In theory, consolidation should reduce the number of support personnel, but this has not yet been proven. The ILC team is taking reasonable steps through its testing and evaluation to ensure that appropriate personnel changes are made.

Another challenge is the support requirement needed to execute these new logistics processes in a combat environment. The change from mass to information and speed will require increased command, control and transportation assets (e.g. radios, communication networks, helicopters, trucks, etc.).

> The implications of this proposed concept [ILC] are enormous from an operational perspective. In order to actually operate in this manner, we would need a distribution capability that relies heavily on air support and a Command & Control capability that allows us to tailor these [logistics] packages "on the fly" and vector them around the battlefield.
>
> Colonel Grelson

A way to overcome cultural resistance and fears of operational Command and Control capabilities, without physically impacting the warfighter, can be achieved with simulation models. Simulation is a great tool that will allow the Marine Corps to analyze potential problems and benefits of changes to the ground equipment maintenance process without having to dismantle existing infrastructure. In the next chapter we will look at how simulation can be used as a decision-making tool for Marine Corps leaders.

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III. OVERVIEW OF MODELING & SIMULATION

In this chapter we will discuss what modeling & simulation is and its popularity as the research tool of choice. We will conclude by discussing the important steps in conducting a successful simulation project.

A. WHAT IS MODELING & SIMULATION?

In this section we will first provide a few definitions from experts in the field and then we will explain how simulation is becoming the tool of choice for business and the military.

So, what is modeling & simulation? According to David Kelton, Randall Sadowski and Deborah Sadowski, the authors of *Simulation With Arena,* "*Simulation* refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software. In fact, 'simulation' can be an extremely general term since this idea applies across many fields, industries, and applications…Computer simulation deal with models of systems. A *system* is a facility or process, either actual or planed." (Kelton et al., 2002)

According to Les Oakshott, Senior Lecturer in the Department of Mathematical Sciences, University of the West of England, Bristol and author of *Business Modelling and Simulation,* "A model [is] a simplified representation of a system, where a system refers to any collection of objects or processes that interact in some way." (Oakshott, 1997) For example, our model represents the "collection of [maintenance] processes that interact" with each other in order to satisfactorily return a weapon system to the warfighter in an operational condition. Therefore, simulation is a tool to understand how the maintenance processes interact in order to produce a FMC weapon system.

"Simulation in general is to pretend that one deals with a real thing while really working with an imitation. In operations research the imitation is a computer model of the simulated reality. Also, a flight simulator on a PC is a computer model of some aspects of the flight: it shows on the screen the controls and what the 'pilot' is supposed to see from the 'cockpit'". (Pollatschek, 2002)

The increased performance of computers has allowed business and the military to take advantage of the benefits simulation has to offer. Business is using simulation to design new products. For example, Boeing relied heavily on computer simulation for the design, testing and construction of its latest commercial jet, the 777. The military is continuing to discover the usefulness of simulation to design logistics processes, weapon systems and warfighting tactics.

B. STEPS IN A SIMULATION PROJECT

Like any project, simulation requires that certain steps be taken in order to ensure success. There is no formal procedure for conducting a simulation project but there are important general guidelines that will provide a framework for our use of simulation. Our research focuses on identifying general steps that a novice simulation user could readily understand. There are eleven general steps that will govern the development of our simulation models for this thesis. These steps come from Oakshott's book with amplification from Kelton, Sadowski and Sadowski.

1. Formulate the Problem and Plan the Study

In order to determine if you are using an analysis tool correctly you must first understand the problem. Most mistakes in simulation are made at this point because the analyst misunderstands what the problem is or the client fails to adequately communicate the problem. For our thesis the problem is based on how to reduce RCT in the Marine Corps' maintenance process. The ILC team has hypothesized that RCT will be reduced by reducing the EOM. Our study will test the ILC hypotheses by analyzing whether the new maintenance process will perform as predicted. We will then examine ways that RCT may be further reduced.

2. Collect and Analyze the Data

For many simulation projects this can be the most time consuming step. An analyst must understand the current system well enough to know what is causing the problem as well as what is the best way to collect the data needed. For our data collection we referenced recent CNA and RAND studies which contain most of the data necessary for our baseline simulation model. In May of 2001, CNA conducted a baseline study of time allocation by maintenance and supply personnel in the 2nd FSSG. In order to collect this data, CNA asked Marines to fill out time sheets for 10 days excluding weekends and holidays. Maintenance personnel were asked to record the amount of time required to conduct the following maintenance activities:

- Accepting inspections, troubleshooting, ordering parts, repairs, quality control, administration, supervising, outside their MOS, mentoring and other. (Heybey, 2001)

Supply personnel were requested to record the amount of time required to conduct the following supply activities:

- Property management, document control, fiscal management, warehouse, outside their MOS, supervising, mentoring, and other. (Heybey, 2001)

3. Build the Conceptual Model

"A conceptual model is essentially a model where mathematical and logical relationships are defined. A diagram showing the inter-relationships between the main parts of the model will help make the model development easier." (Oakshott, 1997) After the CNA data was analyzed for usability, we developed a conceptual model using the ARENA software package. ARENA allows development of a conceptual model by utilizing high-level constructs, which consist of process flow and decision points. ARENA's use of Graphical User Interface (GUI) makes this step fairly easy for novice simulation users. Those familiar with process flow diagramming can construct a conceptual model with minimal difficulty.

4. Check the Validity of the Conceptual Model

Once the conceptual model is constructed it is important to check its validity. Normally the analyst will have meetings with the client or project team to compare step-by-step the conceptual model against the actual model. The client or project team may identify some inconsistencies between the conceptual model and the system. This is the time to make any corrections before developing the detailed computer model. “It is very easy for an analyst to make an incorrect assumption, perhaps as a result of an inadequate understanding of the system. Time spent identifying these errors at this stage will save much time later on.” (Oakshott, 1997)

In our research we first relied upon the CNA analysis of the system and supplemented the report with Major Landry’s experience as a Maintenance Management Officer. Based on these two sources we determined that our conceptual model adequately represents the current and predicted future maintenance processes.

5. Develop the Computer Model

Since we were able to use the ARENA 5.0 software to develop the conceptual model, the process of building the actual computer model of the current and predicted future maintenance processes was streamlined. ARENA is an excellent software package for both the novice or expert simulation model builder. Because of its flexibility and ease of use, many Marines could learn how to develop “what if” scenarios for many processes. Marines can develop high-level constructs in minimal time by learning some statistical methods and utilizing a mouse to click on the template icons. In some circumstances the complexity of a process may require writing specific simulation language, which the ARENA software can provide.

Therefore, based on the versatility of ARENA, we have been able to develop a useful simulation model. Most of our simulation model is developed from high-level constructs. The simulation is largely built around process modules of each step along the maintenance system. Within each process module a triangular or uniform distribution of the process time for a typical Marine is specified based on the findings of the CNA baseline report, RAND study or personal experience.

6. Verify (or Debug) the Computer Model

With the data collected and the model built, the next phase is to verify that the model will run**.** This part of the process will most likely take some time and is often very frustrating. Our goal during this phase was just to get the simulation model to calculate RCT. Of course we did experience logic errors that had to be identified and corrected. Another great aspect of the ARENA software is that it will identify the type of error and direct you to the module with the problem.

7. Validate the Model

After verifying that the model runs, the next step is to make sure that the model replicates the real maintenance process, otherwise known as validating the model. "The easiest and often the most important is the face validation. A face validation simply asks whether, on the surface, the model appears to be replicating the real system." (Oakshott, 1997) ARENA provides easy to view animation that allows us to validate that each step of the process is operating as intended.

Our best measure of validation is the average RCT of 53 days, which the CNA study reports as the current Marine Corps' average RCT. We have validated that the current maintenance system model is behaving properly based on the CNA baseline study, the RAND study and personal experience with the system.

8. Design Experiments

Once we validated that the baseline model is correct, we developed experimental scenarios to test ILC hypotheses and answer our thesis questions. This phase in the process allows us to develop "what if" scenarios in order to predict whether or not the proposed maintenance process will perform as predicted and whether or not further improvements can be made. According to Oakshott, to achieve this in simulation, we need to consider the following factors:

- Type of system
- Length of each simulation run

- Number of independent simulation runs
- Initial conditions for a simulation run
- Length of any 'warm-up' period
- Whether 'variance reduction techniques' need to be considered
- Number of experiments that are to be carried out on the model

Our first scenario deals with the thesis question of what is required in order to reduce RCT from 53 days to 34 days, or a 35 percent reduction. We will discuss the details of our scenarios in the next chapter.

9. Make Production Runs

For some simulation models, numerous production runs must be executed in order to obtain useable results. "Generally, models of non-terminating systems take longer for results to be obtained, as these models have problems with initial conditions, which need to be removed before results are collected." (Oakshott, 1997) For our simulation scenarios we ran 30 production runs, each 365 days in length and eight hours per day.

10. Analyze Output Data

Once the simulation scenarios have made the necessary production runs, the results must be analyzed. Our method of analysis is based on comparing the experimental results against the baseline model in order to answer our thesis questions. In order to properly compare, the results must be presented in a logical and understandable format. Fortunately, ARENA provides easy to read and understandable reports from which to extract the necessary data of RCT for each production run.

11. Write the Report and Make Recommendations

Without this step the entire project is a failure. "As with most management reports, the report should aim to satisfy three type of readers – the non-technical and/or busy manager who wants the main results and recommendations from the study, a reasonably numerate person who wants to see justification for the conclusions reached, and the person who wants a detailed description of the model and results." (Oakshott, 1997) Our thesis chapter VI titled *Recommendations, Conclusions and Areas of Further Research* will satisfy the "non-technical and/or busy manager." Our thesis chapter V titled *Analysis of Simulation Results* will meet the need of those "who need justification for the conclusions reached."

C. CHAPTER CONCLUSION

In this chapter we presented three sources that described modeling & simulation as a tool to imitate the actions of a real system. In our research we will use computer simulation to imitate the actions of the current and future ground equipment maintenance process. We also showed that simulation is gaining in popularity as the research tool of choice, including in the military. We concluded this chapter by discussing one approach to conducting a successful simulation project. In the next chapter we will present our ARENA 5.0 simulation model of the current ground equipment maintenance process and our scenarios that test future process designs.

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IV. SIMULATION MODEL DEVELOPMENT

In this chapter we will present an overview of our simulation model, as well as some assumptions that went into its development. We will then present the baseline simulation model of the current Marine Corps ground equipment maintenance process. This model will serve as a baseline for our three different scenarios. Our first scenario presents the ILC concept of consolidated maintenance. This model will predict the reduction in RCT from just the elimination of 2nd EOM. Our second scenario will build on the results of the first scenario by analyzing potential RCT reductions through the streamlining of the process. Our third scenario will embellish the second scenario by examining what changes are required for the maintenance process to reduce RCT by 50 percent (from 53 days to 26.5 days).

A. MODEL DEVELOPMENT

1. Overview & Assumptions

ARENA provides easy to use graphical user interface, which makes designing the model much easier than having to learn and write simulation code (e.g. JAVA, C++ or Visual Basic). Two important aspects to consider when developing a simulation model are: (1) The model must sufficiently replicate the real-world system; (2) it must be easy enough to understand and use by decision makers.

ARENA allows us to develop sophisticated models that are accurate portrayals of the Marine Corps ground equipment maintenance process. At the same time, these models are easy enough for decision makers to learn from and utilize. We have carefully balanced our model-making decisions in order to minimize the complexity; therefore, we have concentrated our efforts on examining the macro-level of the maintenance process.

In order to further minimize the complexity of the model, we have made the following assumptions regarding the current and future ground equipment maintenance processes:

Assumption 1 – There is not a shortage of capable mechanics to perform maintenance when required. Therefore, a queue is never created from a lack of mechanics. Based on the CNA study, mechanics spend only two out of eight hours on average in the process of repairing vehicles.

Assumption 2 – There is not a shortage of tools for the mechanics to complete the maintenance activity. Therefore, a queue is never created due to the lack of tools. Based on the CNA study, mechanics reported no substantial shortage of tools.

Assumption 3 – There is not a shortage of maintenance facilities. Therefore, a queue is never created due to a lack of maintenance facilities. According to the CNA and RAND studies, the lack of maintenance facilities did not substantially impact RCT.

2. Terminating vs. Non-terminating Systems

An important aspect to consider when building the model is whether the current maintenance process is a terminating or non-terminating system. A terminating system is one in which there is a permanent starting condition and a defined point at which the system ends. When a terminating system reaches its ending condition, there are no customers or entities left in the system. Therefore, at the next defined starting point the system starts from a permanent empty state.

A non-terminating system has neither a permanent starting condition nor a normal ending point in which the system is empty. The system is continuous with customers or entities being carried over from one day to the next as Work-In-Process (WIP) inventory. Our model is an example of a non-terminating maintenance repair process; therefore, the steady state of the system must be determined. There are two main methods for determining the steady state of a simulation model. First, you can use the batch means method in which you "…make one very long run of the simulation and halt it at regular intervals. At the end of each interval, statistical information would be recorded for that interval or batch. The data before steady state is reached can be discarded and only data from that point need be analyzed." (Oakshott, 1997).

The other method is to conduct steady state analysis by plotting data points on a graph. This method is the easiest because it allows you to visually identify the steady state condition of the system. The ARENA simulation software package allows us to automatically display data points as the simulation is running. Therefore, we can visually inspect the point at which our model of the current ground maintenance process reaches its steady state by monitoring the operational availability plot counter. Based on the CNA study, motor vehicles maintained an operational readiness range of 75.5 to 90.4 percent. Therefore, for the purpose of our research we determined that a steady state condition for the system is reached at 80 percent. In order to achieve this 80 percent steady state condition, the simulation requires a 30-day warm-up period.

B. SIMULATION MODEL OF CURRENT PROCESS (BASELINE MODEL)

Our baseline model simulates maintenance repair actions from 1st EOM to 3rd EOM. It includes OST delays, which are calculated from April 22, 2002 Marine Corps OST data. The construction of our model is based on the October 2001 CNA study. Appendix A contains CNA's 1st through 3rd EOMs workflow diagram of the current Marine Corps ground equipment maintenance process. We will detail how we built the ARENA model for each maintenance action using this CNA workflow diagram. We will conclude this section by providing a list of input variables that determine the behavior of the model.

1. ARENA Model of the Current Process

Our ARENA model of the current Marine Corps ground equipment maintenance process is presented in Appendix B. We will describe the workflow through the maintenance process from 1st EOM to 3rd EOM. The measurement of RCT starts once a truck fails at 1st EOM and stops once the truck is returned to 1st EOM Fully Mission Capable (FMC). Therefore, we will first explain the model starting with 1st EOM.

To start a simulation model entities must first be created, which in our model are represented by motor transport vehicles. We based the number of vehicles in the system on the number maintained by the Transportation Support Battalion, 2nd FSSG, IIMEF, Camp Lejeune, North Carolina. This battalion maintains approximately 100 trucks.

An exponential distribution was assumed with an MTBM of 1,500 hours. The mean value was estimated by measuring the operational availability range of the simulation model. An MTBM of 1,500 and an average RCT of 53 days maintained an operational availability of 80 percent, which is the steady state of our system. We assumed that most NMC maintenance problems would require 2nd or higher EOM; therefore, time accumulated at the 1st EOM is assumed to be minimal and therefore has very little effect on RCT. Once the operator identifies a problem with his vehicle he immediately drives or requests a tow to the 2nd EOM shop.

Once the vehicle is at 2nd EOM, the Quality Control (QC) inspector will conduct an acceptance inspection to determine if all 1st EOM has been completed. If all 1st EOM has been completed the vehicle is accepted into the shop. Since there is very little maintenance an operator can perform, the 2nd EOM QC will accept most vehicles. But there are a few occasions when proper preventive maintenance has not been completed (e.g. proper cleaning or lubrication of the vehicle). When this occurs the vehicle is not accepted and the operator must perform any 1st EOM that has been identified. Once the problem is corrected the vehicle is accepted by 2nd EOM.

According to a RAND baseline study, vehicles are not normally worked on as soon as they enter 2nd EOM. Instead there is a delay, which we identify in our model as awaiting inspection. After this delay, a mechanic is assigned to conduct a detailed inspection in order to determine the cause of the failure. The mechanic must trouble-shoot the cause of the failure and determine if it requires 2nd or 3rd EOM repairs. In a few cases the cause of the failure cannot be repaired at 2nd EOM and the vehicle must be evacuated immediately to 3rd EOM. But in a majority of the cases there will be a number of 2nd EOM repairs that must be performed before the vehicle is FMC or in a condition to be evacuated for further repair action at 3rd EOM.

If the cause of the failure is determined to require 2nd EOM work, then the mechanic conducts technical research using the Technical Manual (TM) to determine the parts required for repair. After this, the mechanic must annotate those repair parts and any repair actions on the Equipment Repair Order (ERO). At this point there is another decision the mechanic must make. The mechanic must determine, based on his technical research, whether the repair can be partially or totally completed from available inventory. 2nd EOM does not carry a large inventory of parts, but it may have items such as screws, bolts, washers and tubing that are normally ordered in bulk and maintained in what are called preexpended bins. For example, if one vehicle requires a 3/8th inch bolt, the mechanic will look in the preexepended bin for any 3/8th inch bolts. If there are no 3/8th inch bolts he will order a pack of 100. Once he receives the pack he will use one and put the remaining 99 in the preexpended bin for future use.

A majority of the time the mechanic will need to order the repair part from a source of supply. Again the mechanic will conduct technical research to determine the repair part National Stock Number (NSN) and annotate his order using the Equipment Repair Order Shopping List (EROSL). The 2nd EOM supply shop uses this EROSL to order the repair part via an Automated Information System (AIS) called SASSY/ATLASSII+ (Supported Activity Supply System/Asset Tracking for Logistics and Supply System Two Plus). The order is first transmitted to the local retail supply level called the SASSY Management Unit (SMU). The SMU determines if they have the part in stock or if they need to pass the order to be filled by a wholesale supplier. Based upon April 22, 2002 OST data, we calculated that 60 percent of all repair parts are filled from local retail stocks maintained at the SMU. The other 40 percent is filled from various wholesale suppliers.

According to the CNA study, there is a tremendous delay in the receipt of the necessary repair parts. This delay is the capacity bottleneck of the current ground maintenance process. In other words, this delay in the receipt of repair parts is the main driver in RCT. According to the CNA study, "…short parts were repeatedly cited as driving the repair cycle time."

When the part is received, the mechanic begins to repair the vehicle. Once the vehicle has been repaired it receives a final inspection by the QC. In a few occasions, repair does not pass QC and the mechanic must fix any remaining problems. Once the vehicle passes inspection, the QC must analyze the situation and determine if all repairs are complete or if the vehicle still needs further repairs at 3rd EOM. If all repairs are complete, 1st EOM is notified to come and pick up the vehicle. 1st EOM accepts the vehicle from 2^{nd} EOM and the measurement of RCT is complete. The vehicle is now considered FMC and is operationally available to conduct any unit mission.

However, in the majority of cases all repairs to the vehicle will not be completed by 2^{nd} EOM, and it will have to be evacuated to 3^{rd} EOM. At this point the vehicle is either towed or driven to the 3^{rd} EOM shop, which is normally located in close proximity to the 2^{nd} EOM shop. At the 3^{rd} EOM shop the vehicle undergoes an acceptance inspection in order to determine if all 2^{nd} EOM repairs have been completed. Surprisingly, according to the CNA study, 9 out of 10 vehicles are rejected during this inspection process for incomplete 2^{nd} EOM repairs. Therefore, 90 percent of all vehicles must return to 2^{nd} EOM shops for rework.

The vehicle is inducted into the 3^{rd} EOM shop once the 2^{nd} EOM repairs have been satisfactorily completed. The 3^{rd} EOM process follows the same workflow as 2^{nd} EOM. Once the vehicle has been repaired and passes QC, 2^{nd} EOM is notified that the vehicle is ready for pick-up. After 2^{nd} EOM accepts custody of the vehicle, it notifies 1^{st} EOM that the vehicle is ready for pick-up. 1^{st} EOM accepts the vehicle from 2^{nd} EOM and the measurement of RCT is completed. The vehicle is now considered FMC and is operationally available to conduct any unit mission.

We have outlined the components of our ARENA model that simulates the workflow of the current ground equipment maintenance process. Next, we will describe the input variables that drive this model.

2. Input Variables

All simulations require input data and variables in order for the model to function. We will now describe the delay times and decision variables that populate our model. It was very challenging to obtain values for delay times and decision variables since there is very little reliable data available. Our variables come from either the CNA study, RAND study or from personal observation of the system. For the delay variables we will use the triangular and uniform probability distributions. “The triangular distribution is commonly used in situations in which the exact form of the distribution is not known, but estimates (or guesses) for the minimum, maximum, and most likely values are available.

The uniform distribution is used when all values over a finite range are considered to be equally likely. It is sometimes used when no information other than the range is available. The uniform distribution has a larger variance than other distributions that are used when information is lacking." (Kelton et al., 2002).

Table 1 provides a summary of the delay and decision variables used in this baseline model and the source for each data set.

Variable	Distribution/Value	Source
Truck Fails	*Exponential (MTBM) 1,500 hours*	*Estimated*
Mode of Transportation to 2nd EOM	*40% Towed to 2nd EOM*	*Observation*
Travel to 2nd EOM	*Uniform (15,30) minutes*	*Observation*
Towing to 2nd EOM	*Triangular (4,8,12) hours*	*Observation*
2nd EOM Accept QC	*Triangular (.5,1,1.5) hours*	*Observation*
1st EOM Complete	*75% 1st EOM Complete*	*Observation*
Awaiting Inspection at 2nd EOM	*Uniform (1,2) days*	*RAND baseline study*
Inspection In Progress at 2nd EOM	*Uniform (1,5) days*	*RAND baseline study*
Requires 2nd EOM Repairs	*75% Require Repairs*	*Observation*
Technical Research and Paperwork at 2nd EOM	*Triangular (20,64,100) minutes*	*Estimate based on CNA baseline study*
Repair from available inventory	*10% From Inventory*	*Observation*
Technical research and paperwork for 2nd EOM part	*Triangular (20,64,100) minutes*	*Estimate based on CNA baseline study*
Wholesale source of supply	*40% From Wholesale SOS*	*Calculated from OST data*

Table 1. Input Variables for Baseline Model

Variable	Distribution/Value	Source
Awaiting repair parts 2nd EOM wholesale	Triangular (11,24,84) days	Calculated from OST data
Awaiting repair parts 2nd EOM retail	Triangular (1,11,71) days	Calculated from OST data
Repairs in Progress 2nd EOM	Uniform (1,7) days	RAND baseline study
Final Inspection at 2nd EOM	Triangular (2,4,8) hours	Observation
Repair passes QC	90% Pass 2nd EOM QC	Observation
2nd EOM rework	Triangular (4,8,12) hours	Observation
Reinspection by 2nd EOM QC	Triangular (.5,1,2) hours	Observation
All repairs complete	50% 2nd EOM Completed	Observation
Notification and QC by 1st EOM	Uniform (1,1) days	RAND baseline study
Mode of transportation to 3rd EOM	30% Towed	Observation
Towing to 3rd EOM	Triangular (8,12,24) hours	Observation
Travel to 3rd EOM	Triangular (1,2,4) hours	Observation
3rd EOM Accept QC	Triangular (.5,1,1.5) hours	Observation
2nd EOM Completed	10% Repairs Completed	CNA baseline study
2nd EOM Completes Repairs	Triangular (4,8,12) hours	Observation

Table 1. (cont) Input Variables for Baseline Model

Variable	Distribution/Value	Source
Awaiting Inspection at 3rd	*Uniform (1,2) days*	*RAND baseline study*
Inspection in progress at 3rd EOM	*Uniform (1,5) days*	*RAND baseline study*
Technical research and paperwork at 3rd EOM	*Triangular (20,64,100) minutes*	*Estimate based on CNA baseline study*
Repair from 3rd EOM available inventory	*25% Of Parts Available*	*Observation*
Technical research and paperwork for 3rd EOM	*Triangular (20,64,100) minutes*	*Estimate based on CNA baseline study*
Wholesale source of supply for 3rd EOM	*40% From Wholesale SOS*	*Estimate based on OST data*
Awaiting short parts 3rd EOM wholesale	*Triangular (11,24,84) days*	*Estimate based on OST data*
Awaiting short parts 3rd EOM retail	*Triangular (1,11,71) days*	*Estimate based on OST data*
Repair in progress at 3rd	*Uniform (1,7) days*	*RAND baseline study*
Final Inspection at 3rd	*Triangular (2,4,8) hours*	*Observation*
Repairs pass QC 3rd EOM	*90% Pass QC*	*Observation*
3rd EOM rework	*Triangular (1,2,4) hours*	*Observation*
QC reinspection	*Triangular (.5,1,1.5) hours*	*Observation*
2nd EOM Notified	*Uniform (1,3) days*	*RAND baseline study*
1st EOM Notified	*Uniform (1,1) days*	*RAND baseline study*

Table 1. (cont) Input Variables for Baseline Model

C. ILC PROPOSED PROCESS – SCENARIO 1

Scenario 1 is constructed in order to examine our primary thesis question. Will the elimination of identified non-value added activities in the maintenance process be sufficient to meet the Marine Corps' RCT goal of 34 days by FY 2006 (a 35 percent reduction)? Scenario 1 takes the baseline model of the current Marine Corps maintenance process and applies the ILC initiative of consolidating 2nd EOM at the intermediate level within FSSG. This scenario is based on the first ILC hypothesis:

- **Hypothesis 1**: Support will become more responsive to the customer as there will be fewer non-value added steps and thus a direct link to the intermediate level of maintenance.

This ILC initiative of consolidation will "improve support to the warfighter, remove logistics burdens from the warfighter and allow him to focus on his core competencies." (Heybey, 2001) With the consolidation of 2nd and 3rd EOM, a number of redundant processes will be eliminated which is predicted to reduce RCT.

Our simulation model of Scenario 1 removes all 2nd EOM processes and allows for the direct transfer of NMC vehicles from 1st EOM to 3rd EOM. Appendix C is where we present Scenario 1. Table 2 below lists the input variables that have been deleted from Scenario 1.

Variable	Distribution/Value	Source
Mode of Transportation to 2nd EOM	*40% Towed*	*Observation*
Travel to 2nd EOM	*Uniform (15,30) minutes*	*Observation*
Towing to 2nd EOM	*Triangular (4,8,12) hours*	*Observation*
2nd EOM Accept QC	*Triangular (.5,1,1.5) hours*	*Observation*
Awaiting Inspection at 2nd EOM	*Uniform (1,2) days*	*RAND baseline study*
Inspection In Progress at 2nd EOM	*Uniform (1,5) days*	*RAND baseline study*
Requires 2nd EOM Repairs	*75% Require Repairs*	*Observation*
Technical Research and Paperwork at 2nd EOM	*Triangular (1,1.5,3) hours*	*Estimate based on CNA baseline study*
Repair from available inventory	*10% Parts Available*	*Observation*
Technical research and paperwork for 2nd EOM part	*Triangular (1,1.5,3) hours*	*Estimate based on CNA baseline study*
Wholesale source of supply	*40% Parts from Wholesale SOS*	*Calculated from OST data*
Notification and QC by 2nd EOM	*Uniform (1,3) days*	*Estimate based on RAND baseline study*

Table 2. Input Variables **Deleted** from Baseline Model

D. ILC PROPOSED PROCESS – SCENARIO 2

Scenario 2 enhances Scenario 1 in order to examine our next two thesis questions. First, given the elimination of non-value added activities in the maintenance process, how much will RCT decrease by reducing the Order Ship Time (OST) for repair parts? Second, given the elimination of non-value added activities in the maintenance process, how much will RCT decrease by reducing administrative burdens on maintenance personnel?

Scenario 2 looks at the direct reduction in administrative tasks and OST as well as indirect reduction in other tasks. For example, we assume that the direct reduction in administrative burden allows the mechanic more time to repair NMC vehicles. We also assume that labor productivity will increase, as mechanics are able to spend more time repairing NMC vehicles. As mechanics spend more time making repairs, they become more efficient and therefore could possibly require less time to complete certain types of repairs. This reduction in both direct and indirect tasks is based on the other two ILC hypotheses:

- **Hypothesis 2**: Economies of scale will be gained as the overall administrative burden associated with monitoring parts (Preexpended bins (PEB)), layettes, maintenance records and the like will be lessened.
- **Hypothesis 3**: Labor productivity will increase, as maintenance sites will have a more streamlined approach due to the elimination of the EOM's and a focus/redefinition of intermediate maintenance.

Because these are only hypotheses, we use a conservative reduction of 10 percent for both direct and indirect tasks. Appendix D contains the diagram flow of Scenario 2. Table 3 lists only the input variables that have been changed from Scenario 1. Table 3 lists the variable, its original distribution value and the new distribution value calculated as a 10 percent reduction or increase from the original.

Variable	Original Distribution/Value	New Distribution Value Given 10% decrease/increase
3rd EOM Accept QC	*Triangular (30,60,90) minutes*	*Triangular (27,54,81) minutes*
Awaiting Inspection at 3rd EOM	*Uniform (1,2) days*	*Uniform (.9,1.8) days*
Inspection in progress at 3rd EOM	*Uniform (1,5) days*	*Uniform (.9, 4.5) days*
Technical research and paperwork at 3rd EOM	*Triangular (20,64,100) minutes*	*Triangular (18,57.6,90) minutes*
Repair from 3rd EOM available inventory	*25% Parts Available*	*No Change*
Wholesale source of supply for 3rd EOM	*40% Parts Available*	*Decreased to 36%*
Awaiting short parts 3rd EOM wholesale	*Triangular (11,24,84) days*	*No Change*
Awaiting short parts 3rd EOM retail	*Triangular (1,11,71) days*	*Triangular (.9,9.9,63.9) days*
Repair in progress at 3rd EOM	*Uniform (1,7) days*	*Uniform (.9,6.3) days*
Final Inspection at 3rd EOM	*Triangular (2,4,8) hours*	*Triangular (1.8,3.6,7.2) hrs*
Repairs pass QC at 3rd	*90% Passed*	*Increased to 95%*
3rd EOM rework	*Triangular (4,8,12) hours*	*Triangular (3.6,7.2,10.8) hrs*
QC reinspection	*Triangular (30,60,90) minutes*	*Triangular (27,54,81) minutes*

Table 3. Input Variables That Have Been Reduced

E. PROPOSED FUTURE PROCESS – SCENARIO 3

Scenario 3 is an enhancement of Scenario 2. Scenario 3 is developed to answer our last thesis question. What is required to reduce RCT by 50 percent? In order to answer this question, we take Scenario 2 and identify any additional non-value activities that the Marine Corps could consider eliminating or reducing. The model of Scenario 3 is presented in Appendix E. The following table lists the non-value activities and the reason that we identified them as having no value to the Marine Corps ground equipment maintenance process.

Non-Value Added or Reduced Activities	Reason
3rd EOM acceptance inspection	*Unnecessary delay*
Awaiting inspection at 3rd EOM	*Unnecessary delay*
1st EOM pick-up of vehicle	*Unnecessary delay*
Reduce Retail SOS Max Value from 63.9 to 40 days	*OST will decrease from ILC Supply Initiatives*

Table 4. Non-Value Added or Reduced Activities

The CNA study found that 90 percent of vehicles were being rejected from 2nd EOM. With the elimination of 2nd EOM this rejection could possibly shift to rejecting vehicles for incomplete 1st EOM. This step in the process adds unnecessary days to RCT. A possible solution could be the annotation of any 1st EOM problems. If there are excessive problems with incomplete 1st EOM, then the commander responsible for that vehicle could be notified for corrective action. But the acceptance of the vehicle at 3rd EOM should never be delayed.

If ILC's third hypothesis of increased productivity of labor is true, there should never be an inspection delay of NMC vehicles. As long as OST is the capacity bottleneck, it is crucial that required repair parts are identified as soon as possible and put on order. Therefore, we propose that the priority of work should be concentrated on the immediate induction and identification of repair parts required to fix a NMC vehicle.

The goal of ILC is to "remove logistics burdens from the warfighter." One less logistic burden is for 3rd EOM to deliver an FMC vehicle to the warfighter instead of requiring the warfighter to arrange and coordinate pick-up. 3rd EOM should have a goal of delivering the vehicle to the warfighter as soon as the vehicle passes QC. It is imperative that 3rd EOM take on the responsibility to ensure that a vehicle is returned to the warfighter, especially since the measurement of RCT will not stop until the vehicle has been made available to the warfighter.

The ILC supply initiatives should offer reductions in the variance of retail OST. The consolidation of selected using unit supply responsibilities at the retail level will eliminate redundancy and reduce variance. Additionally, the Quadrant Model for material management will eliminate redundant inventory and reduce OST. Therefore, we estimate that the maximum number of days to receive a repair part from the retail SOS will decrease from 63.9 days to just 40 days.

F. CHAPTER CONCLUSION

In this chapter we have presented an overview of our baseline simulation model of the current Marine Corps ground equipment maintenance process. We explained each step of the workflow in order to provide an understanding of what goes into calculating RCT. From this baseline we presented Scenario 1, which models the ILC initiative to consolidate 2nd and 3rd EOM. We presented Scenario 2, which builds upon Scenario 1 by displaying possible direct and indirect reductions in the process. In Scenario 3 we expanded Scenario 2 in order to present further non-value added activities that can be eliminated or reduced to cut RCT by 50 percent (from an RCT of 53 days to an RCT of 26.5 days). In the next chapter will present our analysis of these scenarios.

V. ANALYSIS OF SIMULATION RESULTS

In this chapter we present a comparative analysis of our three simulation scenarios against the baseline simulation model of the current Marine Corps ground equipment maintenance process. The baseline simulation model and scenarios were run for 30 replications, with each replication being 365 days/8 hours per day. We first examine the results of our baseline model. Next, we examine the first scenario in order to predict the reduction in RCT by simply eliminating 2^{nd} EOM. Analysis of the second scenario examines a potential RCT reduction assuming the ILC initiatives result in a 10 percent overall reduction in the process. Finally, we analyze the results of the third scenario, which eliminates maintenance steps and reduces the retail supply process in order to decrease RCT by 50 percent (from 53 days to 26.5 days).

The three simulation scenarios are analyzed in the following ways: (1) Presentation of the minimum, average and maximum RCT. (2) Analysis of the system's Work-In-Progress (WIP) by utilizing Little's Law. For the base model and each scenario we assume an 80 percent operational availability (CNA study reports a range of 75.5 to 90.4 percent). (3) Analysis of the cost of maintaining a 90 percent operational availability for each scenario based on the acquisition cost of the Marine Corps Medium Tactical Vehicle Replacement (MTVR), with a unit cost of $135,000.

Table 5 below presents the average, minimum, and maximum RCT for the base model and the three scenarios. In addition, we have calculated the variance and standard deviation for the average RCT. Appendices F through I contain the output data for the base model and the three scenarios respectively. The data contained in these appendices was used to calculate the information found in table 5.

Model	***Avg RCT***	***Variance (Std Dev)***	***Min***	***Max***
Base	53.74	6.76 (2.60)	8.62	139.22
Scenario 1	36.25	4.62 (2.15)	8.03	91.29
Scenario 2	34.07	2.96 (1.72)	7.92	85.69
Scenario 3	26.72	2.50 (1.58)	4.25	80.10

Table 5. Repair Cycle Times in days (Based on 30 Replications)

A. ANALYSIS OF BASE SCENARIO AND SCENARIO 1

Scenario 1 examines the ILC initiative to consolidate 2nd and 3rd EOM. Our simulation results strongly support ILC's first hypothesis:

- **Hypothesis 1**: Support will become more responsive to the customer as there will be fewer non-value added steps and thus a direct link to the intermediate level of maintenance.

By eliminating the 2nd EOM processes, average RCT could potentially decrease by 32.5 percent from the base model (from 53.74 days to 36.25 days).

Our results also reveal that this reduction in RCT will decrease WIP by 32.5 percent from the base model (from 20 vehicles to 13.5 vehicles on average). This reduction in WIP will increase operational availability by 8.1 percent above the base.

Additionally, this decrease in RCT could potentially save the Marine Corps a substantial amount of money. Again, we are assuming that the Marine Corps has established a target operational availability of 90 percent. Based on this target and the baseline model RCT of 53.74 days, the Marine Corps must purchase and maintain an additional 13 vehicles in order to reach this target. At a unit price of $135,000, this would cost the Marine Corps $1.75 million (not including operations and maintenance cost).

Based on Scenario 1, the average RCT of 36.25 would require the Marine Corps to purchase approximately 4 additional vehicles at a cost of $540,000. This RCT reduction would save the Marine Corps $1.2 million.

B. ANALYSIS OF SCENARIO 2

Scenario 2 simulates the consolidation of 2nd and 3rd EOM and the effects of a 10 percent overall reduction in each of the remaining maintenance and supply processes. Our simulation results strongly support two of the ILC's hypotheses:

- **Hypothesis 2**: Economies of scale will be gained as the overall administrative burden associated with monitoring parts (Preexpended bins (PEB)); layettes, maintenance records and the like will be lessened.
- **Hypothesis 3**: Labor productivity will increase, as maintenance sites will have a more streamlined approach due to the elimination of the EOM's and a focus/redefinition of intermediate maintenance.

Given a 10 percent reduction, the RCT decreased by 36.6 percent from the base model (from 53.74 days to 34.07 days). This decrease in RCT reduces WIP by 37 percent from the base model (from 20 vehicles on average to 12.6). Operational availability increases by 9.3 percent above the base.

Given this scenario, the Marine Corps would have to purchase approximately 2 additional vehicles at a cost of $270,000 in order to obtain the Marine Corps' operational availability target of 90 percent.

C. ANALYSIS OF SCENARIO 3

Our research reveals that the predicted ILC reduction of 35 percent RCT is attainable. In Scenario 3 we show that RCT can be reduced even further by eliminating additional non-value added activities and streamlining the retail supply process. Our simulation results show a 50.3 percent reduction in RCT when our recommendations are implemented.

WIP is reduced by 50.5 percent and operational availability is increased to the Marine Corps target of 90 percent. Therefore, there is no need for the Marine Corps to purchase additional vehicles if the maintenance process is able to reduce the baseline RCT by 50 percent.

Table 6 below provides a summary of our simulation results:

	Base	***Scenario 1***	***Scenario 2***	***Scenario 3***
RCT	53.74	36.25	34.07	26.72
		(-32.5%)	(-36.6%)	(-50.3%)
WIP	20	13.5	12.6	9.9
		(-32.5%)	(-37%)	(-50.5%)
Op Avail	80%	86.5%	87.4%	90.1%
		(+8.1%)	(+9.3%)	(+12.6%)
# of Additional Vehicles Required*	13	4	2	0
Cost	$1.75 M	$540 K	$270 K	$0

Table 6. Summary of the Simulation Results. Values in the Parentheses are Percentage Reduction or Increase from the Baseline Model (* to achieve 90 percent Operational Availability)

D. CHAPTER CONCLUSION

In this chapter we presented a comparative analysis of our three simulation scenarios against the baseline simulation model of the current Marine Corps ground equipment maintenance process. The results from the baseline model closely replicate the current maintenance process. Our analysis of the first scenario reveals that by simply eliminating 2^{nd} EOM the Marine Corps is able to obtain a majority of the ILC goal. In the second scenario we demonstrated that by streamlining the maintenance and supply processes by 10 percent, the Marine Corps is able to slightly exceed the predicted goal of a 35 percent reduction in RCT. The analysis of the third scenario reveals that the Marine Corps could potentially reduce RCT by 50 percent by eliminating additional non-value added maintenance activities and streamlining the retail supply process. In the next chapter we will present our thesis conclusions, recommendations and areas of further research.

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VI. CONCLUSIONS, RECOMMENDATIONS AND AREAS OF FURTHER RESEARCH

This chapter presents our thesis conclusions, recommendations and potential areas for further research. First, we present our thesis conclusions based on our four research questions. Then we provide recommendations that may improve the Marine Corps ground equipment maintenance process based on our research. We conclude this chapter by providing areas of further research that can augment our research.

A. CONCLUSIONS

Our research tested the ILC prediction of at least a 35 percent reduction in RCT by the consolidation of 2nd and 3rd EOMs. Additionally, we were interested in determining what is required for the ground equipment maintenance process to reduce RCT by 50 percent. We proposed four questions to guide us in our research and then developed simulation models to test and provide possible answers to each:

1. Will the elimination of identified non-value added activities in the maintenance process be sufficient to meet the Marine Corps' RCT goal of 34 days by FY 2006 (a 35% reduction)?

The elimination of identified non-value added activities alone is not sufficient to meet the Marine Corps' RCT goal of 34 days by FY 2006. Based on our simulation, the Marine Corps would only be able to reduce RCT by 32.5 percent (from 53.74 days to 36.25 days) by simply eliminating 2nd EOM from the maintenance process. However, reduction in RCT will increase operational availability from 80 percent to 86.5 percent.

Therefore, in order to successfully meet the 35 percent reduction in RCT, the Marine Corps must reduce the cycle time of each of the remaining steps in the maintenance process.

2. Given the elimination of identified non-value added activities in the maintenance process, how much will RCT decrease by reducing the Order Ship Time (OST) for repair parts and reducing administrative burdens on maintenance personnel?

RCT will decrease by 36.6 percent (from 53.74 days to 34.07 days) based on the results from our simulation. A 10 percent reduction in retail OST, administrative burdens and other maintenance and supply processes will allow the Marine Corps to meet the ILC RCT reduction goal. This will result in an 87.6 percent operational availability.

3. What is required to reduce RCT by 50 percent?

The Marine Corps can reduce RCT by 50 percent by eliminating the following maintenance delays: 3rd EOM acceptance inspection, 3rd EOM awaiting inspection and 1 1st EOM pick-up. These activities are sources of excess delay due to gray areas of timeliness and requirements for benchmark reporting on the Status of Resources and Training System (SORTS). Eliminating these delays and reducing the variance of retail SOS through implementation of the Quadrant model will reduce RCT from 53.74 to 26.5 days. Therefore, the Marine Corps can obtain a 90 percent operational availability by reducing RCT by 50 percent through the elimination of these non-value added activities and the reduction of retail SOS variance.

B. RECOMMENDATIONS

These thesis questions guided our simulation development and testing. Through our testing and analysis we were able to synthesize the problems facing the Marine Corps ground equipment maintenance process. Additionally, our testing and analysis lead us to possible solutions to those problems, which the Marine Corps can consider when implementing the current ILC initiatives or developing future initiatives. The following is a list of the problems we discovered and our proposed solutions:

1. Problem – Within the Marine Corps' maintenance repair process there is high variability and many non-value added activities.

Solution – Implement ILC initiatives to help reduce RCT by FY 2006. A substantial amount of duplicated effort or non-value added activities and variability would be eliminated with the consolidation of 2nd and 3rd EOM. Therefore, the Marine Corps will obtain a majority of its goal by implementing this ILC initiative, which will provide more responsive support to the warfighter.

2. Problem – Within the Marine Corps' supply chain process there is high variability and many non-value added activities.

Solution – The implementation of the supply Quadrant model along with consolidation of supply processes will substantially contribute to the reduction of RCT. The reduction in duplicated effort and non-value added activity for retail supply should remain the focus of effort for ILC. Any further substantial decrease in RCT will depend on the reduction of supply process variance and the elimination of non-value added supply activities.

3. Problem – The ILC initiative of consolidating 2nd and 3rd EOM is not enough to meet the Marine Corps goal of reducing RCT 35 percent by FY 2006.

Solution – A conservative reduction of 10 percent among the remaining maintenance and supply processes will allow the Marine Corps to reach its goal of a 34 day RCT. ILC should establish this 10 percent reduction as a milestone goal. Therefore, economies of scale of at least 10 percent will be gained as the overall administrative burden associated with monitoring parts is reduced. Additionally, labor productivity could increase by 10 percent, "… as maintenance sites will have a more streamlined approach due to the elimination of the EOM's and a focus/redefinition of intermediate maintenance."

4. Problem – Even with a 35 percent reduction in RCT the Marine Corps will still need to maintain additional inventory in order to meet a target operational availability of 90 percent.

Solution – By reducing RCT 50 percent (from 53.74 percent to 26.72 percent), the Marine Corps will be able to meet a target operational availability of 90 percent without having to maintain additional inventory. Given the implementation of the current ILC initiatives, RCT reduction of 50 percent is obtainable by eliminating the following unnecessary maintenance and supply delays: 3rd EOM acceptance inspection, 3rd EOM awaiting inspection, 1st EOM pick-up and reducing the variance of retail SOS.

C. AREAS OF FURTHER RESEARCH

Our research looks at the macro-level of reducing RCT within the ground equipment maintenance process. We tested current ILC hypotheses and provided possible solutions to problems facing that process. The following is a brief overview of possible future research that can add to the important topic of RCT:

1. Refine the simulation.

One way to improve our simulation model is to analyze additional data that examines more of the micro-level of each individual maintenance process. For example, each of the maintenance steps in the process could be broken down further into more refined elements.

Additionally, a comparative model could be built based on additional data that CNA receives from a follow-up time allocation survey (which will be conducted this summer). This survey will be conducted in the same manner as the October 2001 study. It would be interesting to analyze any statistical differences and apply them to our simulation.

2. Identify methods that will improve wholesale Sources of Supply (SOS).

One continuing problem with RCT is the delay caused by waiting for parts at the wholesale SOS. Research should be based on the Quadrant model, especially critical or bottleneck repair parts. Once a particular part and SOS is identified, simulation modeling could be used to map out the supply process and analyze possible "what if" scenarios that could reduce the cycle time for repair parts. This research could map the process and measure the cycle time from point of ordering until the part is delivered to the mechanic for installation.

3. Identify methods that will improve retail Source of Supply.

Research could analyze the steps needed to improve the consolidated retail source of supply. This research could first identify methods for the retail SOS to meet our recommendations of reducing the maximum lead-time for repair parts from 63.6 days to 40 days. Next, simulation modeling could be used to map out the supply process and analyze possible "what if" scenarios that could reduce the cycle time for repair parts. This research could map the process and measure the cycle time from point of ordering until the part is delivered to the mechanic for installation.

4. Identify methods that will reduce Marine Corps ground equipment maintenance RCT by 60 percent or greater (i.e. prognostics).

Research could build upon our existing model and identify any additional maintenance or supply processes that could reduce RCT by 60 percent or greater. One very interesting area is the role that prognostics could play in reducing RCT. "Prognostics is the prediction of component degradation or impending failure, which will allow maintenance personnel to replace components based on their actual condition. The goal is autonomic logistics, which uses electronic information collected from the aircraft [or any ground equipment] to determine, plan and perform needed maintenance with minimal downtime." (AeroTech News and Review, 2002) The ability to determine and plan repair part requirements could drastically reduce the bottleneck caused by SOSs.

For example, if a transmission in a truck is about to fail, prognostics could identify this as a problem and signal the mechanics that it is time to order a new transmission. The main goal of prognostics is that the new transmission will be ordered and received by the mechanic when the current transmission fails.

5. **Identify methods that will improve personnel constraints.**

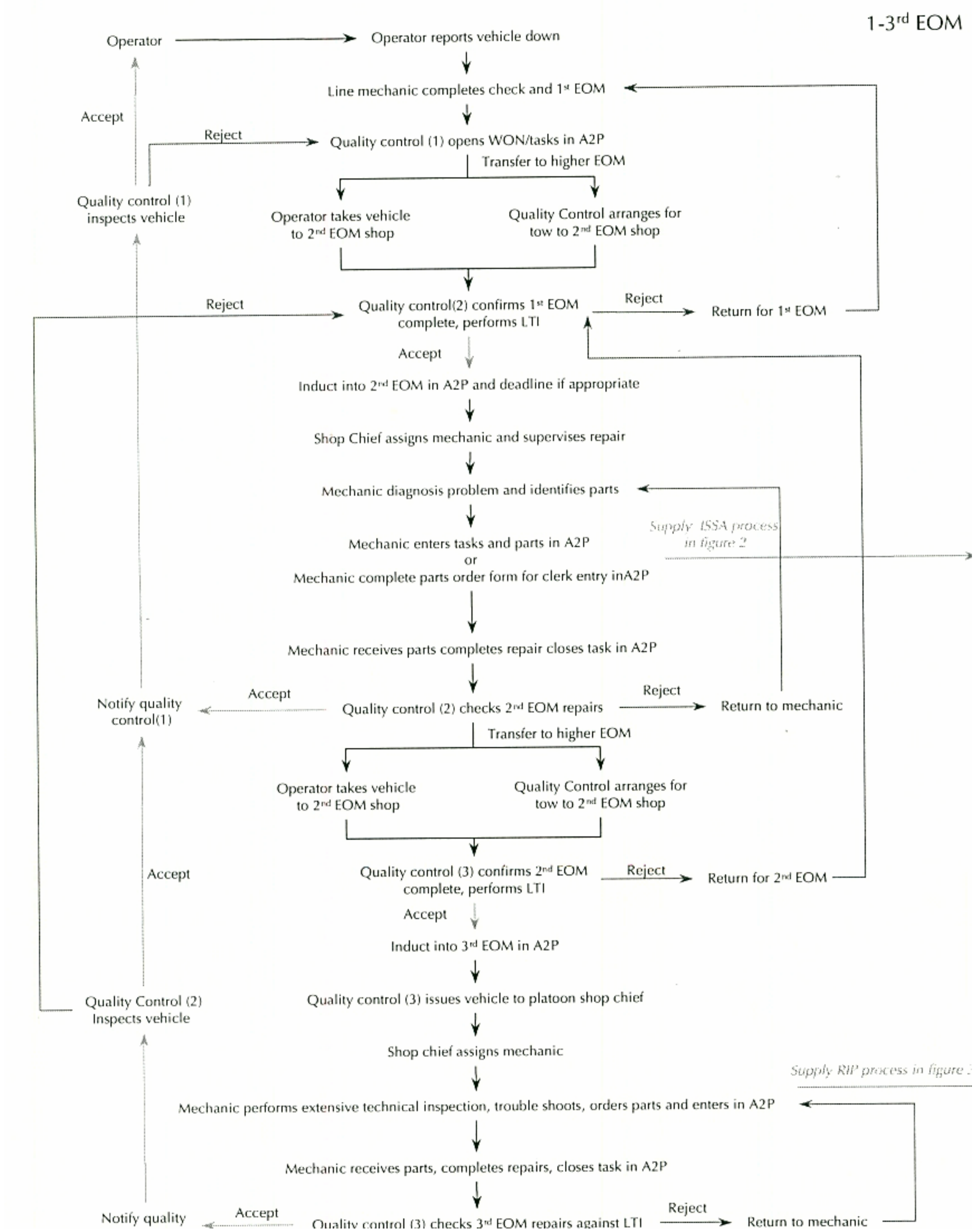
Research could analyze whether consolidated EOM would improve billeting shortfalls. The model could use actual personnel numbers and scheduling constraints throughout each process block. This research could identify possible bottlenecks in the supply and maintenance process and possibly reduce RCT even further.

6. **Identify how using improved MTBM of replacement equipment reduces RCT.**

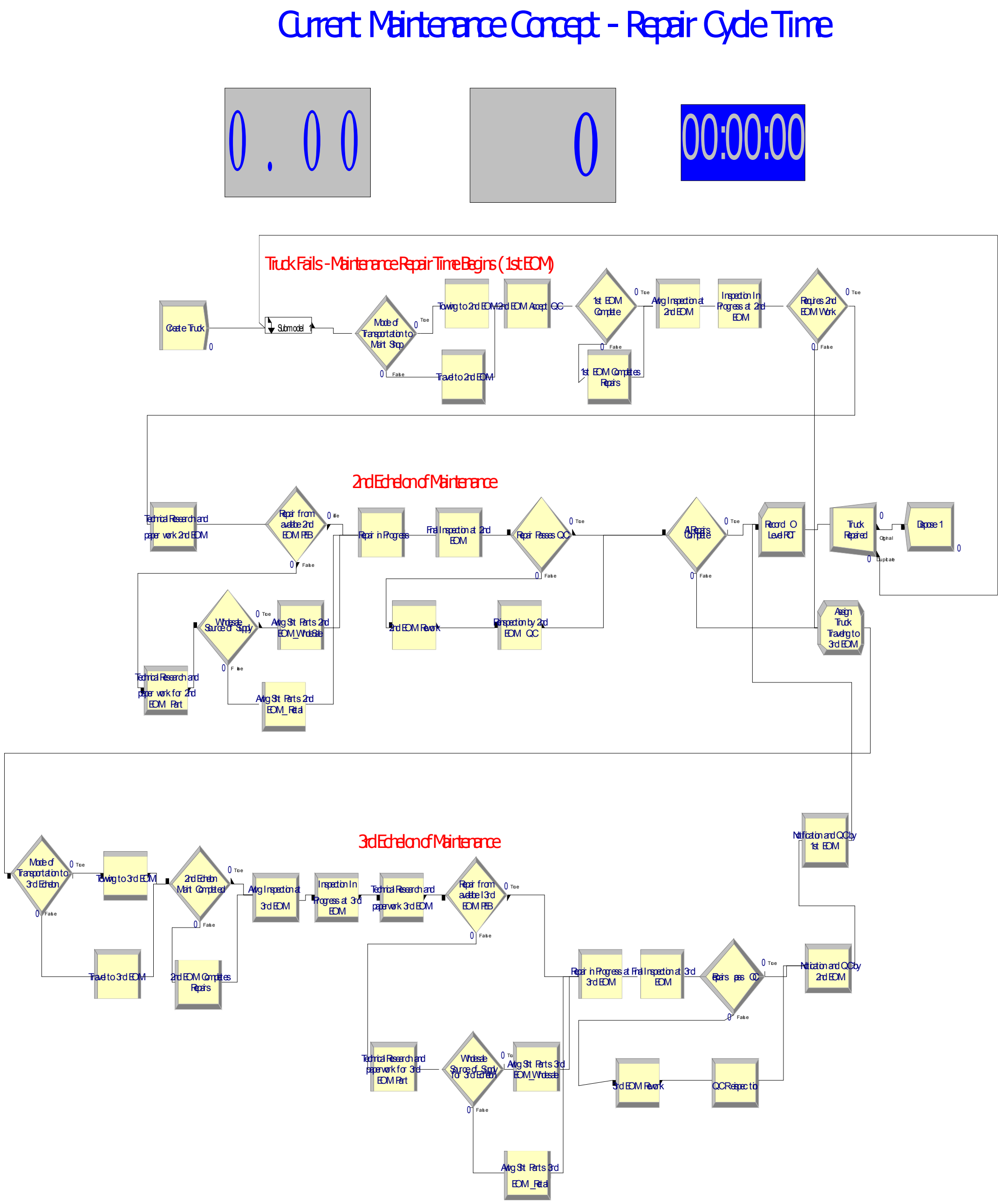
RESEARCH COULD ANALYZE WHETHER INTRODUCING REPLACEMENT EQUIPMENT WITH EXTENDED\IMPROVED MTBM WOULD HAVE AN EFFECT ON RCT. USING THE MODEL CONSTRAINTS, ONE COULD MEASURE HOW IMPROVED MTBM AFFECTS THE VARIABILITY AND RELIABILITY OF THE SYSTEMS, AND THUS AFFECTS THE OVERALL RCT OF THE MAINTENANCE PROCESS. THROUGH THIS STUDY, BENCHMARK MEASURES COULD BE FORMULATED AND USED FOR FURTHER ANALYSIS.

APPENDIX A – CNA WORKFLOW DIAGRAM OF 1ST-3RD EOM

Figure 35. 1st through 3rd EOM process flow



APPENDIX B – CURRENT MAINTENANCE PROCESS



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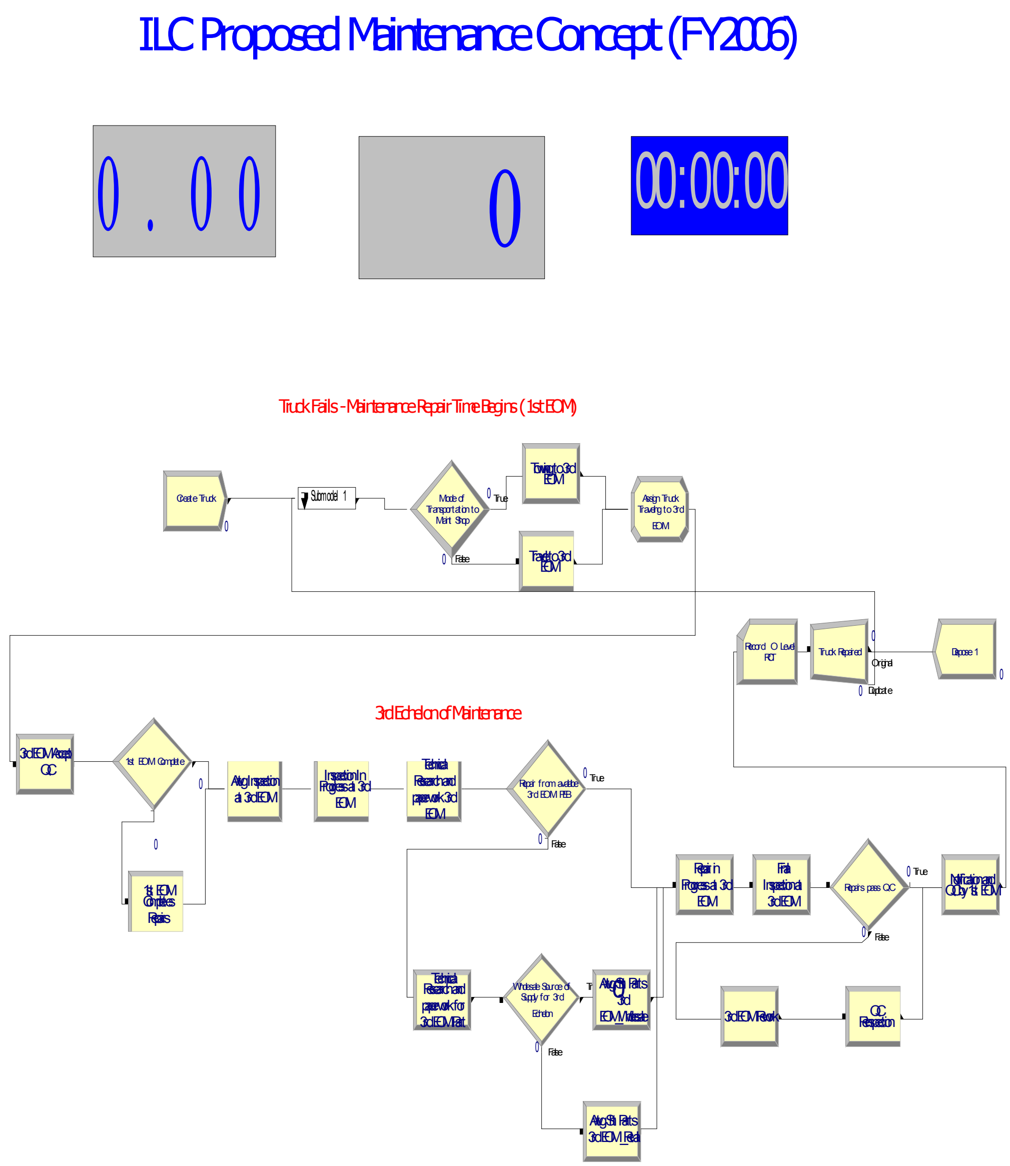
APPENDIX C - ILC PROPOSED PROCESS (SCENARIO 1)
(SCREENSHOT OF ARENA SIMULATION MODEL)



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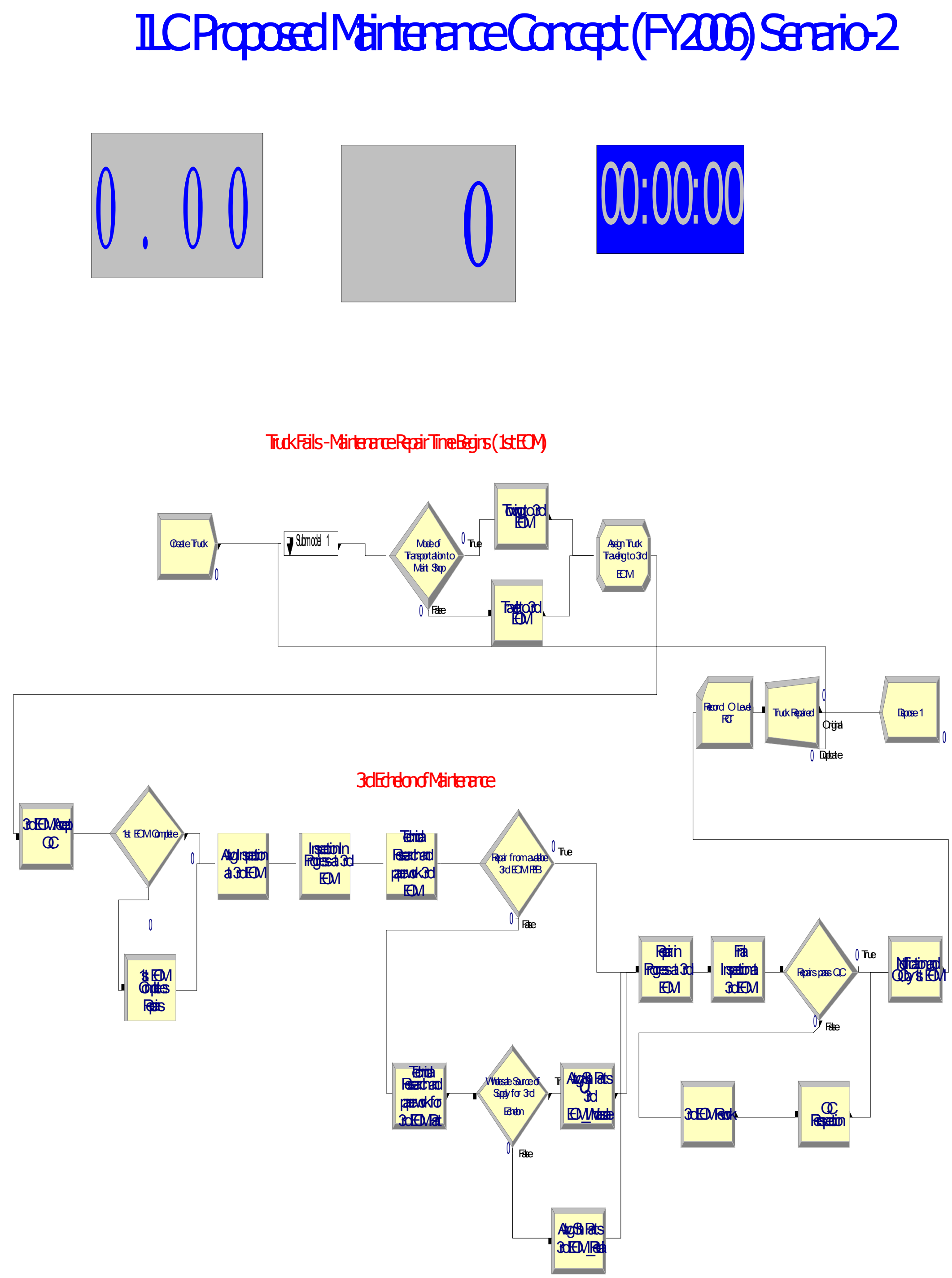
APPENDIX D - ILC PROPOSED PROCESS – SCENARIO 2 (SCREENSHOT OF ARENA SIMULATION MODEL)



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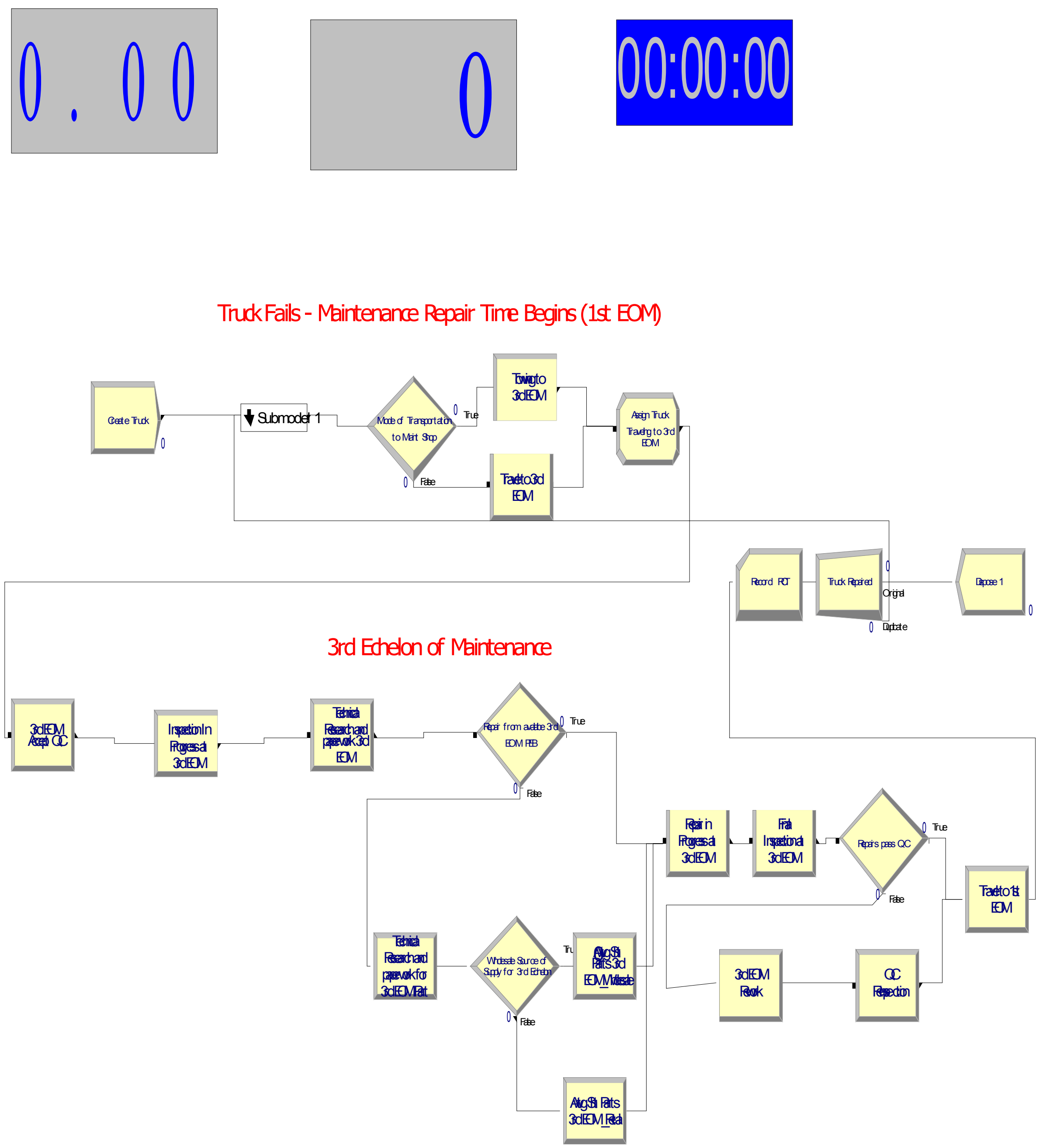
APPENDIX E- PROPOSED FUTURE PROCESS – SCENARIO 3 (SCREENSHOT OF ARENA SIMULATION MODEL)



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APPENDIX F – OUTPUT FROM BASELINE SIMULATION RUN

Replication	*Avg RCT (Days)*	*Min RCT (Days)*	*Max RCT (Days)*
1	51.2668	6.7981	119.25
2	54.3711	10.2837	132.04
3	52.9624	8.2270	134.35
4	55.0183	5.8202	134.91
5	59.6967	8.3307	156.09
6	49.9572	8.1279	127.47
7	54.9889	8.0826	156.00
8	56.5593	10.6817	145.91
9	54.0722	13.4882	131.65
10	55.5761	9.5805	142.07
11	55.8779	11.2435	131.63
12	54.3251	6.6929	142.14
13	50.4344	7.1561	126.21
14	53.4080	6.8515	127.67
15	51.5725	8.9140	126.03
16	53.6324	6.0072	157.87
17	55.9116	8.7771	139.23
18	56.5459	11.6966	136.48
19	52.4540	6.5159	155.93
20	53.2624	8.4860	162.77
21	50.6327	8.0710	123.30
22	52.6281	7.4725	151.53
23	54.5363	9.2328	159.58
24	57.9239	10.1619	135.79
25	48.3986	12.1677	124.25
26	53.6835	10.1554	142.22
27	49.0316	7.0670	132.28
28	54.2470	7.4821	131.12
29	56.5616	8.4867	138.48
30	52.6140	6.6032	152.35

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APPENDIX G – OUTPUT FROM SCENARIO 1 SIMULATION RUN

Replication	*Avg RCT (Days)*	*Min RCT (Days)*	*Max RCT (Days)*
1	35.0907	8.0305	86.8472
2	35.7990	8.9356	87.0285
3	32.4982	7.2248	83.4721
4	31.5124	6.1380	73.2134
5	37.0196	9.3691	85.9684
6	33.0411	8.2576	80.4670
7	34.6772	8.4331	82.7992
8	37.8286	9.2859	92.7045
9	36.9298	7.9834	89.9034
10	37.3255	8.6996	87.0659
11	38.2282	8.2998	87.2604
12	33.8360	8.7154	80.9124
13	36.5766	6.8464	87.8263
14	37.2819	7.2503	97.9935
15	34.9317	7.7318	84.9360
16	37.0206	8.0534	96.9702
17	34.7442	8.1064	92.5025
18	41.7565	7.9465	89.2445
19	35.7312	7.7575	91.8140
20	36.0702	8.7064	90.6842
21	38.3077	8.1659	94.0466
22	35.8496	7.8716	90.8995
23	38.7727	7.9746	94.0288
24	34.7945	8.8118	93.5993
25	33.4420	7.4472	94.4855
26	38.4381	6.4286	85.0439
27	37.7262	8.3098	89.6520
28	37.5973	7.0112	85.9260
29	36.9339	7.9170	87.8059
30	37.8609	9.3264	86.6648

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APPENDIX H – OUTPUT FROM SCENARIO 2 SIMULATION RUN

Replication	*Avg RCT (Days)*	*Min RCT (Days)*	*Max RCT (Days)*
1	34.3219	8.4118	89.4009
2	32.1878	7.2882	83.4358
3	35.5799	8.9023	92.1436
4	32.5040	6.8022	91.2934
5	33.8281	7.8952	73.7187
6	29.0876	8.1771	83.1818
7	32.8069	6.8605	78.9105
8	36.8465	7.5171	95.6140
9	31.9045	9.0035	93.3638
10	35.1157	7.9210	85.7301
11	32.3459	7.4194	88.7289
12	34.3963	9.3502	85.6383
13	34.9625	8.7466	82.5736
14	34.6832	7.2642	92.5311
15	35.3163	7.2026	77.8674
16	32.4648	8.5278	90.0233
17	33.5711	8.2725	85.7075
18	36.2221	8.8594	84.0595
19	35.6208	7.8811	87.8022
20	34.4007	7.8244	79.4639
21	34.3142	7.7982	80.7124
22	35.7896	6.5496	85.9917
23	35.7098	8.2544	96.7993
24	36.9586	8.0547	88.1852
25	31.7350	6.7534	85.1084
26	34.7720	8.7423	92.3364
27	34.5850	8.6166	87.1936
28	33.0462	6.9828	71.2630
29	33.2717	6.3444	79.2723
30	33.8511	9.3657	82.7182

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APPENDIX I - OUTPUT FROM SCENARIO 3 SIMULATION RUN

Replication	*Avg RCT (Days)*	*Min RCT (Days)*	*Max RCT (Days)*
1	26.0051	3.2802	80.0608
2	26.7296	4.8836	87.5605
3	24.9468	3.7269	75.0868
4	24.0913	3.2784	78.2489
5	27.2736	4.1987	78.6768
6	26.3554	3.8132	85.6491
7	28.3760	4.4998	85.9060
8	28.1743	3.9605	76.3918
9	27.3573	3.7624	82.9902
10	27.5347	3.5047	81.4084
11	25.8881	3.8118	78.2804
12	24.6056	3.9214	70.7252
13	25.2097	3.8533	81.9036
14	27.5760	4.6942	81.2642
15	25.4810	3.9279	80.7566
16	25.5491	5.4727	79.2478
17	27.4788	4.7427	80.3852
18	27.9663	4.4118	80.1081
19	29.8537	3.5588	88.6111
20	27.1340	4.2579	79.0422
21	28.9148	5.0146	80.1077
22	27.1392	5.0849	84.9481
23	30.2184	4.9670	86.9348
24	25.6312	4.9162	74.5685
25	23.8078	4.1411	76.9923
26	26.4291	4.8366	78.3146
27	27.0712	4.0009	80.3495
28	26.5667	4.7353	79.7938
29	27.6456	4.0341	70.7565
30	24.5608	4.7269	77.9871

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   Camp Pendleton, California

7. Head of Integrated Logistics Capability Center
   Headquarters Marine Corps
   Washington, D.C.

8. Professor Keebom Kang
   Naval Postgraduate School
   Monterey, California

9. Professor Ira Lewis
   Naval Postgraduate School
   Monterey, California

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